ACIDIC PRECIPITATION IN ONTARIO STUDY (APIOS)

PROJECT SUMMARIES: 1990-1991

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Acidic Precipitation Office
Ontario Ministry of the Environment

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PREFACE

As a result of the findings of the Sudbury Environmental Study and Lakeshore Capacity Study, the Acidic Precipitation in Ontario Study (APIOS) was established in 1979 to investigate the long range transport of air pollutants and particularly those pollutants associated with acid deposition in Ontario. The program is managed through six working groups or tasks (Atmospheric Processes, Aquatic Effects, Terrestrial Effects, Environmental Management and Economics, Laboratory Support and Methodology, and Communications). The APIOS program operates on a five year planning cycle.

Up until 1990, a comprehensive annual program report has been prepared which encompasses the progress of all projects within each task. The format for presentation has been changed this year and the contents consist of a compilation of Project Summary Sheets for the Atmospheric Processes, Aquatic Effects, Terrestrial Effects tasks and the Acid Precipitation Office. Information for Laboratory Support and Methodology studies and Environmental Management and Economic Analysis studies has not changed significantly from the previous annual report and have, therefore, not been included.

A separate document entitled "Acidic Precipitation in Ontario Study (APIOS) - Publications" has been prepared which lists all publications and technical reports associated with the APIOS program since its inception in 1979. General information on acid rain and the Countdown abatement program are available upon request from the Ontario Ministry of the Environment's Public Information Center at (416) 323-4321.

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TASK 1

ATMOSPHERIC PROCESSES

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Compilation of an Ontario Gridded Carbon Dioxide and Nitrous Oxide Emission Inventory

Project Leader:

S. Wong

Purpose

To prepare a detailed emission inventory of carbon dioxide and nitrous oxide for the Province of Ontario.

Background:

There is widespread concern in the international scientific community that certain gases released by human activities, mainly related to the use of energy, are now building up to concentrations large enough to affect the global climate, through a process known as the "green house effect".

Carbon dioxide is one of the major contributors to the green house effect. Global CO_2 concentrations are presently rising at a rate of three to four percent per decade. The primary cause of the CO_2 emissions is the burning of oil, natural gas and coal.

Nitrous oxide is a naturally-occurring gas which has increased significantly in recent years due to human activities such as the application of fertilizers and the burning of fossil fuels. Scientists have estimated that even though the concentration of nitrous oxide is much less than that of carbon dioxide in the atmosphere, nitrous oxide has a much higher global warming potential (which is an index to compare the ability of various green house gases to absorb long wave radiation and thus heat the lower atmosphere).

Project Description:

The Ontario CO_2 and N_2O gridded inventory was prepared for the base year 1988, using methodology developed by Environment Canada, specific data compiled by the Ontario

Ministry of Energy, and other information sources. Emission factors were applied to available point and area source base quantity data for each contributing process, in order to compile anthropogenic CO_2 and N_2O emissions by sector and process at the provincial level. In some instances, previously-developed emission factors were refined or verified by available source test data, some new sources were added and the major natural source emissions were estimated and included in the inventory. Emissions attributable to various public service sectors and specific industrial source fuel contributions were derived and specified at the provincial level, to indicate relative sector contributions.

Product:

A technical report describing the methodologies and the results of the study is currently being finalized by the contractor. The data compiled in this study will be arranged in PC Focus database files.

Publications/Reports/Presentations:

Ortech International: Compilation of an Ontario Gridded Carbon Dioxide and Nitrous Oxide Emission Inventory. Final Report. No. P-91-50-6436/OG, September 1991.

External Cooperation:

This work has been developed in consultation with the Ministry of Energy and Environment Canada.

Application of Results:

The results will be used in development of global warming strategy and to monitor effectiveness of limitation measures.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Acid Rain/Toxic Gases Emission Data Base Update, Maintenance and Data Analysis

Project Leader:

S. Wong

Purpose:

- To maintain and update all existing acid rain/toxic emission inventories
- To provide support to management for decision making purposes.
- To provide support for the study of atmospheric transport of toxic pollutants.

Background:

The Ontario Emission Inventory System (OEIS) was developed to identify and quantify major emission sources of acid-rain related pollutants (SO_2, NO_x,VOC). This has been expanded to include other common pollutants such as CO and particulates as well as pollutants of environmental concern such as alkaline dust, ammonia and toxic substances. The information is used to aid in the decision making for management and is also used as input to the long range transport modelling activities. About one hundred and fifty thousand records of point and area sources in several FOCUS and Dbase data bases, are installed on several microcomputer stations linked by a local network system. The system consists of numerous major data groups listed below:

a. Ontario emission inventories of regular pollutants
b. Ontario volatile organic compounds (VOCs)
c. Ontario alkaline dust and ammonia emissions
d. Canada emissions
e. United States power plants
f. United States point sources
g. Metal emissions
h. Several Dbase, FOCUS maintenance, updating and reporting systems

Project Description:

Data analyses on Ontario statistics such as population, fuel consumption, marine, aircrafts, rail road, waste, fire, vehicle registration etc. for 1987 and 1988 were completed and the information was used to update the area source sectors of the OEIS emission inventories.

Point source emissions for 1986/1987 were updated through the process of emission survey questionnaires. Raw data from the survey questionnaires were extracted. Engineering calculations to quantify emissions were performed. The calculated results were then stored into a data handling system where data verification procedures were applied before transferred to the final data base.

Automobile emissions of NO_x and VOC were updated with the EPA Mobile 4 transportation model. Mobile 4 transportation model was acquired, installed and modified for Ontario conditions (i.e. car fleet, registration, mileage distribution, temperature etc.).

Product:

Up-to-date emission information are presented in the Fast Reference Emission Document (FRED) published semi-annually. Data input for the long-range transport model and other modelling requests were produced. Information was provided to the Ministry's management, the Federal Government, public agencies, other scientific and environmental interest groups. Emission forecasts, such as SO_x projection, were also generated.

Publications:

1990 Ontario Emission Inventory Fast Reference Emission Document version 2. Ministry Publication, Winter 1990.

External Cooperation:

Conservation and Protection Service of Environment Canada and the U.S. Environmental Protection Agency (EPA) are consulted in the emission inventory activities.

Application of Results:

The results from this project are used in the formulation and management of the NO_x/VOC control programs, in monitoring the effectiveness of control program implementation, in the development of emission forecasts, in detailed studies of the Ontario portion of the Windsor-Quebec City Corridor and in atmospheric modelling studies.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

ADOM Evaluation and Development with EMEFS I data

Project Leader:

C. Fung

Purpose:

To evaluate the Acid Deposition and Oxidant Model (ADOM) using data from the Eulerian Model Evaluation Field Study (EMEFS)

Background:

ADOM was developed to address the question of non-linearity of acid deposition response to emissions change. It has been evaluated with data from a few sources with limited representation. The EMEFS I program, carried out over eastern North America during the summer of 1988, provides the most comprehensive attempt so far to collect and compile quality assured/controlled data in three dimensions to evaluate comprehensive models. The first phase of the evaluation has been completed using surface data.

Project Description:

This effort is part of a cooperative program between the U.S. and Canada to evaluate comprehensive models for simulating acid deposition. Some of the agencies involved in the evaluation part of the work are Ontario Ministry of Environment (OME), Environment Canada, U.S. Environmental Protection Agency (EPA), Electric Power Research Institute of the U.S., Analytical Sciences Corporation and ENSR Corp. of the U.S. A model evaluation protocol was developed by the Model Evaluation Team to provide guidance on the evaluation effort. OME's involvement includes: establishing (constructing and quality checking) the meteorological and emissions data for the period, running ADOM for a particular period, processing and displaying the output data, comparing with observation data, organizing international meetings to interpret the comparison results, investigating the possible causes of any discrepancies and repeating the evaluating process if the findings require. Due to the multi-dimensionality of the model and hence the evaluation effort, this model evaluation process must be organized as an ongoing and iterative process lasting at least a few years.

Product:

During the evaluation process using surface data, a number of inadequacies in the model has been identified and rectified. This includes problems in the preprocessing of the meteorological and emissions data which have gone undetected in previous evaluations that go back four or five years and the discovery of non-precipitating clouds as a major mechanism for converting SO_2 to SO_4^{2-} which until now has not been identified as a significant contributor to the ground level concentrations of sulphate. Also, a number of other processes have been investigated. A paper documenting the results of the evaluation have been prepared for submission to a journal and a Ministry's green back report has also been published.

Publications:

Fung C., Bloxam R., Misra P.K. and Wong S. (1991) Understanding the Performance of a Comprehensive Model. Proceedings of the Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, 46-49, Jan 13-18, 1991. New Orleans, Louisiana.

Fung C., Bloxam R., Misra P.K., and Wong S. (1990) Evaluating the Comprehensive Model ADOM. Proceedings of the Ontario Ministry of the Environment's Technology Transfer Conference. Nov. 19-20, Toronto, Ontario.

Fung C., Bloxam R., Misra P.K., Wong S. and Yap D. (1990) Evaluating the Comprehensive Model ADOM with data from Three Seasons. Ontario Ministry of the Environment report log 90-2206-078.

Federal/Provincial Research and Monitoring Coordinating Committee (RMCC) (1990) The 1990 Canadian Long-Range Transport of Air Pollutants and Acid Deposition, Part 3: Atmospheric Sciences.

Fung C., Bloxam R., Misra P.K. and Wong S. (1990) Evaluating the Comprehensive Model ADOM with Data from Three Seasons. Paper prepared for the 18th ITM (NATO/CCMS) Meeting, Vancouver, B.C. May 13-18.

External Cooperation:

This work is collaborated with the Atmospheric Environment Service, Environment Canada, and the U.S. Environmental Protection Agency and the Electric Power Research Institute (EPRI).

Application of Results:

The knowledge that was gained through evaluating the model with just a small fraction of data (surface observation) has produced a wealth of information and enhanced our understanding of the physico-chemical processes of the acid precipitation phenomenon. Further evaluation using more species in full three dimensions will allow us to understand the processes in greater detail. The knowledge gained in the process can be applied to the simulation of toxic transport in the future.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

ADOM response to SO_x emissions change

Project Leader:

C. Fung

Purpose:

To determine the degree of non-linearity in the acid deposition response to changes in precursor emissions using ADOM as a surrogate of nature.

Background:

The Acid Deposition and Oxidant Model (ADOM) was developed to address the issue of non-linear response of acid deposition to emissions change. This is made possible by the incorporation of all the pertinent processes in the model. The model is used to quantify the degree of non-linearity over eastern North America.

Project Description:

ADOM was first run using the emissions and meteorological input data for a summer period in 1988. The output of this run serves as the base case for future comparison. Then SO_x emissions during that period were reduced by 50 per cent across the domain while leaving the other inputs the same as the base case. The results of this run were compared with the base case results and deviations from a linear response (i.e. 50 per cent reduction in all sulphur species) noted.

Product:

The results of this study indicate that the response of sulphur deposition to emissions change is non-linear over the heavy emissions area. However, the degree of non-linearity is small, of the order of a few per cent. Previous studies using data from other seasons produced similar results.

Publications:

These preliminary results have been discussed in a number of conferences.

External Cooperation:

The work is collaborated with the Atmospheric Environment Service, Environment Canada.

Application of Results:

The results of this investigation is preliminary in two ways: the model is still being improved sand this set of results only represents one season. To gain greater confidence in our results, ADOM will have to be further evaluated with data available from the EMEFS program. Sensitivity tests will be made for other seasons in order to aggregate to longer periods.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Development of emissions and meteorological data files for EMEFS II and Nov/Dec 1988

Project Leader:

R. Bloxam

Purpose:

To furnish the necessary input data for evaluating ADOM for a spring and a winter period.

Background:

The Eulerian Model Evaluation Field Study (EMEFS) was initiated to provide data to test Eulerian model performance. The latest field study was done during March - May, 1990. To produce model outputs for comparison with observation, period-specific meteorological and emissions data are required.

Project Description:

The meteorological data are obtained from two sources: Canadian Meteorological Centre (CMC) spectral model output and observations. Recently, the CMC model has been upgraded. To ensure that the meteorological fields generated for the current study are consistent with previous constructions, a comparison was first made between the outputs generated using results from the two versions of the spectral models. On ascertaining the compatibility of the two sets of meteorological data, the processor was run to generate meteorological data by merging observations and spectral model output for the entire period and the quality of these data checked against weather maps.

The emission data are a combination of the 1985 National Acidic Precipitation Assessment Program (NAPAP) emissions inventory, real time data from selected point sources and meteorological driven biogenic and mobile emissions. These data are consolidated into files with format compatible with ADOM input format.

Products:

Period specific meteorological and emissions data files for running ADOM.

Publications:

Selective data will be plotted and documented at the end of the project.

External Cooperation:

The Atmospheric Environment Service of Environment Canada is a co-sponsor of both the meteorological and emissions data construction projects.

Application of Results:

Running ADOM with these data sets will allow the model to be evaluated for a spring and a winter periods. This will be the first time a comprehensive model is evaluated so extensively for these two seasons in all three dimensions. Also, the evaluation based on these two seasons will be the prerequisite for aggregating representative model outputs for various seasons to annual output.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Preparing the SANtiago MODelling (SANMOD) system for application to southern Ontario

Project Leader:

C. Fung

Purpose:

To perform preliminary tests on SANMOD to delineate its applicability.

Background:

The SANMOD modelling system, based on an Eulerian modelling framework, was developed by the ENSR Co. to study urban air pollution in Santiago, Chile which is located in a mountainous region. SANMOD consists of a simple meteorological preprocessor with terrain following features and the dispersion model handles complex oxidant/ozone chemistry. This new model has not been extensively tested.

Project Description:

SANMOD was first installed on OME's computers. Then input data files representing idealized cases of meteorology and chemistry were constructed as input to the model to delineate model response.

An effort to construct a quality controlled gridded meteorological data set by assimilating observation into model output has been initiated. This makes use of the SANMOD preprocessor and the OME meso-scale wind field model.

Products:

A number of problems and potential problems were identified in SANMOD and solutions to the problems were found in consultation with the developer.

Publications:

None at present. A consultant report on the meteorological assimilation will be produced at the completion of the work.

Application of Results:

SANMOD can be applied to the Windsor-Quebec corridor to study the merit of various emission control strategies for ozone abatement. The same modelling framework can also be adapted to study air toxics. The meteorological data set produced as part of this effort can be utilized by other meso-scale models for simulation over southern Ontario.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Regional scale oxidant studies using ADOM

Project Leader:

C. Fung

Purpose:

To determine the effectiveness of various ozone abatement strategies using ADOM as a surrogate for nature.

Background:

Since the Acid Deposition and Oxidant Model (ADOM) has incorporated the pertinent mechanisms (chemistry and meteorological) for the generation and destruction of ozone and that it has been evaluated for ground level ozone concentration, it is used as a tool to evaluate the relative effectiveness of hypothetical abatement strategies.

Project Description:

August 1 - 4, 1988 was chosen as the study period because of the high ozone levels experienced over southern Ontario. ADOM was run with meteorological and emissions data for that period to produce a base case. Six scenarios were made with different and anthropogenic reactive hydrocarbon (RHC) reductions and the results compared to the base case results:

1. 50 per cent reduction of emissions across the entire domain
2. emissions totally eliminated in Ontario
3. 50 per cent reduction of RHC across the entire domain
4. RHC emissions totally eliminated in Ontario
5. RHC totally eliminated in the U.S.
6. RHC totally eliminated across the entire domain

Products:

The results of this study agree with previous findings that NO_x control is more effective than RHC control. At the same time, none of these controls is totally effective in eliminating ozone exceedance from the province. Some peculiarities in the way the ADOM handles ozone under certain conditions have also been noticed. This will require further studies.

Publications:

A Ministry's report is currently being prepared.

External Cooperation:

The work under this project will involve Environment Quebec and Ontario Hydro.

Application of Results:

The results of this study are preliminary. Since the resolution of the present utility of ADOM does not allow application down to the urban scale, which is the scale of concern, these results serve as a direction pointer to further modelling on finer spatial resolutions using other models or modified versions of ADOM.

MODELLING METEOROLOGY AND ASSESSMENT
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Model long range transport, transformation and deposition of mercury species.

Project Leader:

R. Bloxam

Purpose:

The objective of this study is to integrate the best available data on mercury emissions, dry deposition, scavenging and chemistry into a model to examine the deposition loading on lakes and land surfaces.

Background:

Concern about the buildup of methylmercury in fish in remote lakes as well as the Great Lakes has resulted in studies of the role that atmospheric transport plays in the mercury cycle. Indications from a number of studies suggest that atmospheric transport and deposition are the primary source of total mercury in remote lakes. A joint project involving Ontario Ministry of Environment (OME), Atmospheric Environment Service (AES) and GKSS-Forshungszentrum Geesthacht (GKSS) in Germany was initiated to develop mercury models.

Project Description:

For this project the mercury atmospheric system is assumed to consist of 3 components: Hg°, particulate mercury and divalent mercury (i.e. Hg Cl_2 or HgO). The elements needed to put together a model of mercury are:

1. emission rates for the 3 species for anthropogenic and natural sources;
2. inferred or measured information on dry deposition;
3. wet scavenging of mercury;
4. dry phase chemistry; and
5. aqueous phase chemistry.

The framework of the ADOM model has been adopted for this mercury modelling. The partitioning of mercury between the 3 species is a major concern since their wet scavenging and dry deposition characteristics are very different. Elemental mercury which includes most of the emissions is very insoluble and would thus be scavenged or dry deposited slowly. The other mercury species would be scavenged or dry deposited quickly which would strongly affect deposition patterns.

Since many of the elements needed for a mercury model are poorly known, the project has proceeded in steps. A preliminary model was developed to allow initial comparisons with the few air and precipitation measurements available. The emission, chemistry and physical information on mercury is then to be updated to reflect the best current knowledge. Since many elements will still be poorly known a series of sensitivity tests will be used to estimate the degree of uncertainty in modelled air concentrations and deposition of the mercury species. These results would then be compared with observations before performing base case model runs over a long meteorological data set.

Product:

In the 1990-91 fiscal year a preliminary 3 species mercury model was produced and the model was run for a five day period in April 1981 Oxidant Scavenging and Characteristics of April Rain (OSCAR). The results from the last 2 days of model runs are summarized below:

1. Air concentration of Hg° were in the 1 to 3 ng m^{-3} range which are similar to the average observed values of 1.5 to 4 ng m^{-3} away from source areas.

2. Modelled air concentrations of HgII and particulate mercury were less than 0.05 ng m^{-3} using 5% of total emissions for each of these species. Very few reliable observations exist. Measured average particulate values in the New England area were ~ 0.06 ng m^{-3} while values in Wisconsin averaged ~ 0.02 ng m^{-3}.

3. Concentrations of HgII and particulate mercury in precipitation varied strongly with precipitation amount which is consistent with rapidly scavenged species. For moderate precipitation areas both HgII and particulate mercury concentrations in precipitation were in the 0.5 to 4 ng l^{-1} range.

   On the other hand, scavenging of Hg° produced only about 1 ng l^{-1} of mercury in precipitation.

   The total modelled values of 3 to 7 ng l^{-1} in moderate precipitation is lower than the observed values of 10 to 20 ng l^{-1} but it must be kept in mind that the speciation of the emissions was very crude.

Based on information obtained at a mercury conference and workshop in Sweden in 1990, model modifications were proposed for anthropogenic emission speciation and griding, natural emissions, aqueous chemistry, boundary values for mercury species and for the dry deposition

rates of the mercury species. By March 1991 modified anthropogenic mercury emission inventory was available (total emissions are still poorly known) and most of the above mentioned model modification had been implemented. The next stage of the project will be to run a series of model sensitivity tests on emissions, dry deposition rates, aqueous phase oxidation and the final products of oxidation, and the boundary values for air concentrations coming into the model domain. The final stage in this project would be a longer model simulation to estimate wet and dry deposition rates for annual or seasonal mercury deposition. This information would then be used to estimate mercury loading to the Great Lakes or to remote lakes in Ontario or northeastern North America.

Publications/Reports/Presentations:

Petersen, G., B. Schneider, D. Eppel, H. Grassl, A. Iverfeldt, P.K. Misra, R. Bloxam, S. Wong, W.H. Schroeder, E. Voldner and J. Pacyna 1990; presented at 18th Int. Tech Meeting on Air Pollution Modelling and its Applications, Vancouver B.C.: Report # GKS90/E/24 by GKSS, Geesthacht, West Germany.

Bloxam, R.: 1990. Presentation at 2nd International Workshop on Modelling the Atmospheric Transport and Deposition of Mercury, Gavle, Sweden.

Petersen, G.: 1990. Presentation at International Conference on Mercury, Gavle, Sweden.

Bloxam, R. and G. Petersen: 1990 Summary Report: 2nd International Workshop on Modelling the Atmospheric Transport and Deposition of Mercury.

Bloxam R., S. Wong, P.K. Misra, E. Voldner, W. Schroeder, and G. Petersen. 1990: Poster Paper at Ontario Ministry of Environment Technical Transfer Conference, Toronto.

External Cooperation:

A joint project involving our ministry, the Atmospheric Environment Service of Environment Canada, and GKSS-Forshungszentrum Geesthacht of Germany and the Swedish Environmental Institute.

AIR QUALITY AND METEOROLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Meteorological Support Services.

Project Leader:

D.Yap

Purpose:

To acquire and archive meteorological data on an on-going basis so as to provide support for acid precipitation and air toxics studies.

Background:

An operational Meteorological Data Acquisition System (MDAS) has provided on-going support for special studies, episode analyses and modelling activities. MDAS is a computerised system which collects and archives meteorological data supplied by Canada's Atmospheric Environment Service, via a satellite link, from the North American network of weather stations. Air parcel trajectories are generated by the system for interpreting event precipitation and other air quality data.

Products:

- Meteorological and air quality statistics related to long range transport of air masses into Ontario were compiled.
- Routine analyses utilizing existing software to determine relationships between meteorological and precipitation chemistry and air quality parameters were performed.
- Scientific reports were prepared.
- A Data General MV/3500 computer was installed to replace the aged Eclipse S/130.

Publications/Reports/Presentations:

Warmenhoven, H. and D. Yap (1991). Sector Analyses To Examine The Relative Contributions In The United States And Canada Acidic Wet Deposition In Ontario, 1981-1985, MOE Report ISBN 0-7729-6902-7.

External Cooperation:

Linkages with the Ontario Ministry of Natural Resources and Ontario Hydro have been established to provide back-up meteorological data support.

Application of Results:

MDAS data and analyses are used to examine the contribution of emissions in the United States and Canada to acid wet deposition and toxics in Ontario. The purpose of these studies will allow us to identify general source regions that contribute to acid wet deposition and air toxics in Ontario. The system is also used in support of emergency response (nuclear and chemical) and the Air Quality Index/Air Pollution Index and Lambton Industrial Meteorological Alert.

ATMOSPHERIC RESEARCH AND SPECIAL PROGRAMS
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Acid Rain Monitoring

Project Leader:

N.W. Reid

Purpose:

To determine the spatial and temporal patterns of acidic deposition in Ontario, and to evaluate the response of these patterns to emission control measures introduced in Canada and the United States.

To study episodes of acidic deposition, and to use short term monitoring data in conjunction with meteorological information to identify the sources contributing to acidic deposition in Ontario.

Background:

Concerns about acidic deposition in Ontario, and its effects on terrestrial and aquatic ecosystems, have existed for a number of years. Accordingly a province-wide monitoring program was established in 1980. This program was designed to provide good spatial and temporal resolution, and results from the program are integrated into a number of program areas. Thus, data from the monitoring program has provided input to terrestrial and aquatic programs, and has formed the basis for legal initiatives.

Project Description:

Concentrations of acid related species in both air and precipitation are monitored in two networks. In the Daily Network, samples are collected over 24 hours using a three stage filter pack for air, and a wet-only collector for precipitation. The sampling period in the Cumulative Network is 28 days; the sampling equipment is similar to that of the Daily Network.

There are currently 4 sites in the Daily Network, providing data which are used in the study of episodes, and in the identification of trends. The Cumulative Network consists of 19 sites. This network provides the long-term spatial and temporal record of acidic deposition in Ontario.

Product:

Annual reports containing listings and statistical summaries of data. In addition detailed analyses of data are carried out, and are reported in Ministry reports, scientific journals, or at scientific conferences. The data are stored in the APIOS Deposition Monitoring Data Base, maintained by the Air Resources Branch, and are also filed in the Acidic Deposition System (ADS) data base, currently held at Battelle Pacific Northwest Laboratories, and in the NatChem data base at Atmospheric Environment Services in Downsview, Ontario.

Publications/Reports/Presentations:

Green, D. APIOS: 1988 Daily precipitation chemistry listings. ARB-004-90.

Green, D. APIOS: 1988 Daily ambient air concentration listings. ARB-005-90.

Green, D. APIOS: Annual statistics of concentration and deposition - Daily Precipitation and Air Monitoring Network 1988. ARB-002-90.

Green, D. APIOS: Cumulative (28-day) precipitation chemistry listings, 1988. ARB-006-90.

Green, D. APIOS: Cumulative (28-day) ambient air concentration listings, 1988. ARB-007-90.

Green, D. APIOS: Annual statistics of concentration and deposition - Cumulative Precipitation Monitoring Network, 1988. ARB-001-90.

Green, D. APIOS: Annual statistics of concentration - Cumulative Ambient Air Monitoring Network, 1988. ARB-003-90.

Reid, N.W., Shackleton, M.N. and D.B. Orr. An overview: the Toxics Deposition Monitoring Network. ARB-052-90.

Shackleton, M.N. Technical and Operating Manual: Toxics Deposition Monitoring Program. ARB-254-89.

Reid, N.W. and M.A. Lusis. Modelling ozone production in the region of Sarnia, Ontario. NESCAUM Symposium on the control of NO_x and VOC in ozone management. Boston, Mass. 30 May - 1 June 1990.

Air Resources Branch. Ontario Ministry of the Environment Volatile Organic Compounds Monitoring Network Quality Assurance Plan. ARB-021-90.

Steer, P. et al. Occurrence of dioxins and furans in air and vegetation samples from a tire fire in Ontario, Canada. Submitted to Dioxin '90, W. Germany, 1990.

Waddell, D., Chittim, B., Clement, R., Tashiro, C., Davies, S., Szkolcai, A., Steer, P. and T. Dann. Database of PCDD/PCDF levels in ambient air and in samples related to the pulp and paper industry. Chemosphere 20, 1990 (in press).

External Cooperation:

Atmospheric Environment Service of Environment Canada and Batelle Northwest Laboratories are cooperative partners on this project and the development of a Post-1994 Abatement Strategy.

Application of Results:

The results will be in monitoring the effectiveness of the Countdown abatement program and the implementation of the U.S. Clean Air Act Amendments and Post 1994 Strategy.

ATMOSPHERIC RESEARCH AND SPECIAL PROJECTS
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-91

Project Title:

Toxics Deposition Monitoring

Project Leader:

N.W. Reid

Purpose:

To determine the input flux of selected toxic chemicals from the atmosphere to the Great Lakes basin.

Background:

It is recognized that a significant fraction of the input of certain toxic chemicals to the Great Lakes is by direct deposition (both wet and dry) from the atmosphere. A monitoring network has been established to quantify this fraction, and thus to provide input data for the development of abatement strategies.

Project Description:

The list of target compounds includes pesticides, PCB, PAH and trace metals. Concentrations in air are determined over 28 days using a filter pack method (for metals), and on a 4 day in 14 cycle, using a modified high volume sampler for the organic species. Precipitation samples are collected separately for metals and for organics, but the sampling period is 28 days in both cases. The network consists of 6 sites, two on Lake Superior, one each on each of the other lakes having a Canadian shoreline, and one at Dorset. A seventh site is located on the Toronto Islands to provide data on urban influences. This site also provides input data for the Toronto Waterfront Remedial Action Plan.

Close cooperation is maintained with the monitoring work planned and carried out under Annex 15 to the Great Lakes Water Quality Agreement, and also the work in progress in the United States as required under the US Clean Air Act Amendments.

Product:

Annual reports will be produced containing listings and statistical summaries of data. In addition, analyses of data have been reported in scientific journals, and at scientific conferences. The data base for this monitoring program is currently being finalized, and will be maintained by the Air Resources Branch.

Publications/Reports/Presentations:

(see Acid Rain Monitoring)

External Cooperations:

Environment Canada and the U.S. Environment Protection Agency are cooperative partners on this project.

Application of Results:

The results will be used to support the: IJC - transboundary pollution, Contamination of the Great Lakes, Canada-Ontario Agreement, U.S. Clean Air Act Amendments, U.S.-Canada Air Quality Agreement.

TASK 2

AQUATIC EFFECTS

BIOLOGICAL STUDIES

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Monitoring of selected Muskoka-Haliburton lakes for sensitive invertebrate species.

Project Leader:

G. Mierle

Purpose:

To assess the effects of long-term trends in lake and stream chemistry on aquatic biota.

Background:

Several cases of local, abrupt, species extinction in the Muskoka-Haliburtion area have been documented by university researchers. It would appear that, in addition to hydrogenion (H^+) sensitivity, certain life history characteristics lead to a high probability of extinction over a short period of time, even though the degradation of water chemistry may be slight. Thus, it appears that if the right species are selected, there is a reasonable probability that a monitoring programme may detect population losses over a relatively short period of time, e.g. 5 years.

Project Description:

Lakes with a range of sensitivity from ultrasensitive (<5 µeq/L) to low sensitivity (80 µeq/L) will be routinely sampled over an extended period of time for species which are normally abundant, have short life spans, and are believed to be sensitive to H^+. These include gastropods, amphipods, crayfish, leeches, and some insects. A variety of sampling techniques and schedules were tested and compared in the first year. An optimum protocol was devised, which will be used in the succeeding years of the study. The monitoring data will be integrated with the Department of Fisheries and Oceans (DFO) monitoring project, and the combined data sets will be used to examine regional as well as temporal trends in community composition. Enumeration of the 1988 and 1989 samples were completed in 1990.

Product:

A technical report on an intensive crayfish trapping study has been released, and a technical report on the littoral benthic invertebrates is near completion. The data collected have been organized under the Oracle database management system.

Publications/Reports/Presentations:

Reid, R.A. and S.M. David. 1990. Crayfish distribution and species composition in Muskoka and Haliburton lakes. Ministry of the Environment Data Report DR 90/1.

Application of Results:

The results will be used to document ecosystem damage from acid deposition and the extent of recovery from the sulphur control programs implemented by Canada and the U.S.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Surveys of lakes in the Muskoka-Haliburton area for sensitive aquatic species to determine sensitivity as a function of lake chemistry.

Project Leader:

G. Mierle

Purpose:

1. To determine the mathematical relationship between alkalinity and the frequency of occurrence of species or groups of species that are known or are suspected to be sensitive to low pH.
2. To characterize and compare the littoral zone invertebrate communities of circumneutral and acidic, low alkalinity lakes.

Background:

Much of the concern over the anthropogenic acidification of Ontario lakes and streams has been directed towards its adverse effects on sport fish. In recent years, however, it has become apparent that the most sensitive aquatic organisms are a variety of benthic invertebrates that form the main part of the diet for sport fish. In order to quantify these damages, biological surveys of softwater Ontario Shield lakes will be conducted.

Project Description:

The littoral zone invertebrate community was sampled at 5 stations in approximately 60 lakes during the fall of 1987. Concurrent water samples were taken for chemical analysis. Additional samples were collected in the fall of 1988 to augment the data on low alkalinity lakes. The biological samples are currently being processed to identify specimens to lowest possible taxon. The biological and chemical data will be subjected to multivariate statistical analysis to determine if any significant correlations exist between the chemical parameters and the occurrence of particular biota or various community parameters.

Product:

Samples have been collected and have been enumerated.

Publications/Reports/Presentations.

The final consultant's report on data analysis is pending.

External Co-operation:

M. Stevenson, Freshwater Institute, Department of Fisheries & Oceans
G. Mackie, Trent University, Peterborough

Application of Results:

The results of this study will be used to document ecosystem damage from acid deposition.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Effects of acidification on the zooplankton littoral micro-invertebrate communities of Precambrian Shield lakes in Ontario.

Project Leader:

N. Yan

Purpose:

1. To determine if the acidification of lakes in Ontario directly or indirectly influences the taxonomic composition, size, structure, predator: prey ratios, productivity, temporal variability, or biomass of zooplankton communities. Microcrustacea, the most important plankters, are emphasized, but effects on rotifers and phantom midges (Chaoborus) are also being assessed.
2. To determine the rate at which, and the degree to which, normal zooplankton communities are re-established following experimental or natural water quality improvements in acidic lakes following neutralization.
3. To determine the influence of acidification on littoral microcrustacea.
4. To determine if there are any linkages between lake water acidification and the accumulation of trace metals in zooplankton.

Background:

This is an ongoing project that forms part of the documentation of the impact of acid deposition on the biology of aquatic ecosystems and potential food chain impacts.

Project Description:

The objectives are being addressed by a combination of intensive, long-term monitoring of plankton from carefully selected lakes, extensive monitoring of 55 lakes distributed along a gradient of pH in south-central Ontario, synoptic sampling of several hundred lakes distributed across Ontario, and experimental manipulations and modelling exercises designed to test hypothetical mechanisms responsible for observed community alterations.

Product:

An analysis of a province-wide data base established that acidification of lakes has had widespread direct effects on one of the most important zooplankton taxa in Ontario. Model calculations of invertebrate predation in a non-acidic lake near Sudbury established that substantial changes in zooplankton size and taxonomic structure in acidic lakes could be indirectly attributed to changes in predation pressure. A comparison of current zooplankton assemblages of Sudbury lakes with historical communities and non-acidic reference lakes established that zooplankton communities may recover in response to improvements in water quality (Keller and Yan under review). Analysis of samples has been completed by staff of the National Museum of Nature. An analysis of survey and experimental data indicated that metal levels of zooplankton are influenced by acidity and humic content of lake waters, and by zooplankton community composition, physiological status and animal behaviour.

Publications/Reports/Presentations:

Keller, W., L.A. Molot, R.W. Griffiths and N.D. Yan. 1990. Changes in the zoobenthos community of acidified Bowland Lake after whole-lake neutralization and lake trout (Salvelinus namaycush) re-introduction. Can. J. Fish. Aquat. Sci. 47: 440-445.

Yan, N.D., G.L. Mackie and P. Grauds. 1990. Control of cadmium levels in Holopedium gibberum (Crustacea, Cladocera) in Canadian Shield Lakes. Environ. Toxicol. Chem. 9: 895-908.

Yan, N.D., W. Keller, H.J. MacIsaac and L.J. McEachern. 1990. Regulation of zooplankton community structure of an acidified lake (Swan Lake, Canada) by the invertebrate predator, Chaoborus. Ecolog. Applicat. (in press).

Yan, N.D., G.L. Mackie and P.J. Dillon. 1990. Cadmium concentrations of crustacean zooplankton of acidified and non-acidified Canadian Shield lakes. Env. Sci. Technol. 24: 1367-1372.

Keller, W., N.D. Yan, K.E. Holtze and J.R. Pitblado. 1990. Extinctions of Daphnia galeata mendotae by lake acidification. Env. Sci. Technol. 20: 1259-1261.

Yan, N.D. and P.M. Stokes. 1990. The impoverishment of aquatic communities by smelter activities near Sudbury, Canada in G. Goodwell (ed.), The Earth in Transition, Patterns and Processes of Biotic Impoverishment, Cambridge University Press. (in press).

Keller, W. and N.D. Yan. 1990. Recovery of crustacean zooplankton species richness in Sudbury area lakes following water quality improvements. Can. J. Fish. Aquat. Sci. (in press).

Yan, N.D. and G.L. Mackie. 1990. Contributions of zooplankton to the total cadmium pool in Canadian Shield lakes varying in acidity. Water Air Soil Pollut. (in press).

Johannsson, O.E., M.A. Shaw, N.D. Yan, J.M. Filion, S. Lawrence and D.S. Malley. 1990. A comparison of freshwater zooplankton sampling gear: nets, traps and submersible pump. Canadian Journal Fish and Aquatic Science (submitted).

External Co-operation:

W. Keller	(MOE, Sudbury)
R. Chengalath	(National Museum, Ottawa)
D. Lasenby	(Trent University, Peterborough)

Application of Results:

The results of this study will be used to document the impact of acid deposition on the biology of aquatic ecosystems and potential food chain impacts.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Ecological impact of acid precipitation on stream insects in Algonquin Park, Ontario.

Project Leader:

R. J. Hall

Purpose:

To determine if changes in stream insect communities have occurred due to increased acidification in Algonquin Park, Ontario.

Background:

This project will add to the documented evidence on the effects of increasing and decreasing acid deposition on the biology of aquatic ecosystems.

Project Description:

Detailed, quantitative studies of stream insect populations were made about 50 years ago at several sites in Algonquin Park. Although much of the data was never published, many of the original records have been obtained from one of the researchers (F.P. Ide). New collections are being made at the same sites using modern collecting methods as well as the original techniques. Comparison of the new data to the historical records will reveal: 1) if the modern methods were comparable to the original techniques, 2) if changes in insect species have occurred at the various sites, and 3) if the biomass and size distribution of emerging insects have changed. These results will be related to water chemistry and pH tolerance data to determine if the area has been acidified since the original collections and if recovery of acid-sensitive insects can be positively correlated with recently reduced deposition of acid precursors.

Major activities for fiscal year 1990 included 1) resurvey of chemistry and invertebrates in Mud and Costello Creek in Algonquin Provincial Park to assess possible recovery due to reduced acidic deposition, 2) development of the invertebrate data base in the Oracle database management system, 3) preparation of report on chemical and biological data summary for

Mud Creek and Costello Creek in Algonquin Park, 4) preparation of report on factors regulating stream invertebrate communities in Algonquin Park between 1937-1990.

Product:

Detailed analyses of the data have been conducted. At a site where current pH fluctuations are small (pH 6.4-6.1), the same insect taxa that were present in 1984-85 were observed one-half century earlier. However, at sites where large pH depressions are currently observed (6.4-4.9), many mayfly and stonefly taxa that were present 48 years ago and that are known to be intolerant to depressed pH (pH <5) were not recorded in 1984-85. Since aquatic insects are integrators of changes in water quality, the loss of the acid sensitive insects indicates that poorly buffered surface waters in this region have acidified sometime within the last 48 years. In addition, large increases in blackflies have occurred in the acidified sites in 1984-86 compared to collections made in the same locations from 1937-1948. Sites that have not acidified within the last 50 years have the same numbers of blackflies between 1937 and 1986. Thus, blackflies have increased as a result of increased acidification.

Publications/Reports/Presentations:

Hall, R.J. and M. Coleman Taylor. 1990. Emergence of Trichoptera from two streams in Algonquin Park, Ontario (submitted for internal review).

Hall, R.J., D.J. Giberson and M. Coleman Taylor. 1990. Emergence patterns and phenology of mayflies (Ephemeroptera) in two streams in Algonquin Park. (Manuscript).

Hall, R.J. and M. Coleman Taylor. 1990. Life histories of stoneflies (Plecoptera) in Ontario streams during 1984-1986. (Draft manuscript).

Chmielewski, C.M. and R.J. Hall. 1990. Responses to immature blackflies (Diptera: Simuliidae) to experimental pulses of acidity. (Draft manuscript).

Chmielewski, C.M. and R.J. Hall. 1990. Evidence of increased blackfly emergence as a result of increased acidification. (Draft manuscript).

Hall, R.J. 1990. Effects of episodic acid disturbances on lake outflow benthic communities at the Experimental Lakes Area, Ontario: an area of low hydrogen ion deposition. Can. J. Fish. Aquat. Sci. (in press).

Hall, R.J. 1990. Relative importance of seasonal, short-term pH disturbances during discharge variation on a stream ecosystem. Can. J. Fish. Aquat. Sci. (in press).

Hall, R.J., R.C. Bailey and J. Findeis. 1988. Factors affecting survival and cation concentration in the blackflies Prosimuluim fuscum/mixtum and they mayfly Leptophlebia cuspida during spring snowmelt. Can. J. Fish. Aquat. Sci. 45: 2123-2132.

Imhof, J.G., N. Kaushik, J. Bowlby, A. Gorden and R.J. Hall. 1989. Natural River Ecosystems: The ultimate integrators. pp. 114-127 in Proc. of the Management of Ontario Streams, Toronto, Ontario.

External Co-operation:

Mary Coleman Taylor	(Ploughgate)
Robert Bailey	(University of Western Ontario, London)
Carol Chmielewski	(Trent University, Peterborough)

Application of Results:

The results of this study will be used to document the effects of acid deposition on the biology of aquatic ecosystems.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Aqueous inputs of mercury to lakes in the Muskoka-Haliburton region.

Project Leader:

G. Mierle

Purpose:

To evaluate (and modify as necessary) a photo-oxidation/solvent extraction technique for preconcentrating mercury from stream, lake and rainwater. To determine the relative importance of terrestrial and atmospheric loadings of mercury by routinely monitoring its concentrations in streams and precipitation, and from hydrologic data. To determine if watershed characteristics can be related to the mercury contamination of streams. To relate mercury concentrations in water to levels in biota.

Background:

Acidified lakes tend to have increased mercury levels. The sources of mercury in sensitive areas and the relationship between mercury concentrations in water to levels in biota need to be clarified.

Project Description:

A photooxidation/solvent extraction procedure was developed for the determination of ultra trace concentrations of mercury in water. The technique was used to analyze stream, lake and precipitation samples in the Muskoka-Haliburton area. By combining these data with hydrologic information, the relative importance of atmospheric vs. terrestrial loading of mercury to lakes will be quantitated. The influence of watershed characteristics on the retention or release of mercury will be examined, and the relationship of mercury concentration in lake water to its concentration in biota will be explored. To determine the cause and extent of severe mercury contamination of fish populations in the lakes surrounding Huntsville, and to assess the concentration of mercury in the Huntsville lakes and streams relative to other area lakes and streams.

Product:

Volume weighted concentrations of mercury are 3 to 5 times higher in precipitation than in runoff. Direct deposition accounts for about half of the mercury input to headwater lakes. Watersheds act as sinks for mercury, not as sources as previously hypothesized. Most of the mercury deposited on watersheds by precipitation is retained. The proportion of atmospherically deposited mercury exported from watersheds varies from about 5% to 30% and is dependent on the export of humic substances, which is determined by the proportion of wetland in the watershed. Mercury concentration in the Huntsville lakes is 2 to 3 fold higher than in other lakes in the area. The high concentration may be due to the exceptionally high fraction of wetland in the Huntsville watersheds and the consequent low retention of atmospherically deposited mercury.

Publications/Reports/Presentations:

Mierle, G. and R. Ingram. 1990. The role of humic substances in the mobilization of mercury from watersheds. Water, Air, Soil Pollut. (in press).

Rasmussen, P. and G. Mierle. 1990. The determination of mercury in vegetation. Water, Air and Soil Pollut. International Conference on Hg in the Environment Proceedings.

External Co-operation:

D. Boomer, D. Russel, ITC, Laboratory Services Branch (MOE)
P. Rasmussen, J. Nriagu (University of Waterloo)

Application of Results:

Improved understanding of the relationship between mercury concentrations in water to levels in biota. Results will be used in the development of mercury control initiatives.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Toxicity of trace metals to native Ontario aquatic biota in soft waters.

Project Leader:

G. Mierle

Purpose:

To determine the lethal and sublethal toxic thresholds of copper and other trace metals to native Ontario biota, and to determine the influence of dissolved organic carbon, pH, and major ions on trace metal toxicity.

Background:

In several cooperative studies with National Water Institute and the University of Waterloo the acute toxicity of several trace metals to fathead minnow larvae in soft water was evaluated. Copper was identified as a metal with markedly greater toxicity in soft water than hard water, and with possible environmental impacts at current levels at atmospheric deposition. The acute lethal concentration was below the present Provincial Water Quality Guidelines, a result which suggested that the PWQO for copper should be revised for softwaters. At present there is insufficient data to meet the requirements for PWQO revisions, and there are no labs in North America with the necessary facilities to conduct long term, low level experiments to provide the required data. To bring together the appropriate facilities and skills to conduct these experiments, the Dorset Research Centre and the University of Waterloo have entered into a cooperative work agreement whereby the Dorset Research Centre will provide facilities and funding, and the University of Waterloo will provide staff to conduct the necessary experiments.

Project Description:

The principal goals for the 1990-91 fiscal year were to construct a clean toxicity laboratory, convert the existing laboratory to a culture facility, to establish cultures of targeted species for toxicity testing, to establish proper working conditions in the clean lab, and to conduct preliminary tests on targeted species.

Product:

Sufficient information will be gathered from the toxicity tests to revise the PWQO for copper for softwaters. Also the results should yield a better understanding of how water quality parameters affect copper toxicity.

Publications/Reports/Presentations:

External Co-operation:

G. Dixon (University of Waterloo)

Application of Results:

Used to revise the Provincial Water Quality Objective for copper for soft waters.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Filamentous Algae

Project Leader:

H. Vandermeulen

Purpose:

1. To determine if acidification directly or indirectly influences the distribution, abundance and taxonomy of filamentous algae in Ontario lakes.
2. Time trend analyses and definition of aquatic effects relative to acid deposition.

Background:

Excessive growth of filamentous algae can have a number of unwanted effects, such as modification of fish habitat, fouling of swimming areas, and reduction in shoreline aesthetics. A survey of over 5,000 cottagers concluded that cloud-forming filamentous algae, predominantly Zygogonium tunetanum, occur in approximately half of the central Ontario study area lakes. Shoreline accumulations of filamentous algae are the single most important concern of cottagers on affected lakes (Dorset staff per. comm., SPR Survey). This is the only project assessing extent and rates of changes of filamentous algae in Ontario. Furthermore, the necessary levels of emission control must be based on the predictability of aquatic ecosystem response.

Project Description:

Shoreline mapping of filamentous algae in experimentally manipulated lakes, and selected central Ontario lakes. Continue long-term biological co-monitoring programme with Dorset Research Centre (filamentous algae component).

Product:

The data will be used to monitor the long term effects of changes in acid deposition rates.

Publications/Reports/Presentations:

Jackson, M.B., E.M. Vandermeer, N. Lester, O.A. Booth, L. Molot and I.M. Gray. 1990. Effects of neutralization and early reacidification on filamentous algae and macrophytes in Bowland Lake. Can. J. Fish. Aquat. Sci. 47: 432-439.

Howell, E.T., M.A. Turner, R.L. France, M.B. Jackson and P.M. Stokes. 1990. Comparison of Zypnematacean (Chlorophytal) algae in the metaphyton of two acidic lakes. Can. J. Fish. Aquat. Sci. 47: 1085-1092.

France, R.L., E.T. Howell, M.J. Patterson and P.M. Stokes. 1990. Relationship between littoral grazers and metaphytic filamentous algae in five softwater Ontario lakes. Hydrobiologia (in press).

France, R.L. and P.M. Stokes. 1990. Influence of lake pH and macrograzers on the distribution and abundance of nuisance metaphytic algae in Ontario, Canada. Can. J. Fish. Aquat. Sci. (submitted).

Vandermeulen, H., M.B. Jackson and A. Rodrigues. 1990. Filamentous algal communities in Sudbury Area lakes: Effects of variable lake acidity. Can. J. Fish. Aquat. Sci. (submitted).

Application of Results:

The results of this study will be used to document ecosystem damage from acid deposition and the extent of recovery from the sulphur control programs implemented by Canada and the U.S.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Phytoplankton - Lake Characterization and Time Trends

Project Leader:

K. Nicholls/L. Nakamoto

Purpose:

1. To characterize the biomass and species composition (seasonal) of several acid sensitive lakes in central Ontario relative to circum-neutral and moderately well buffered reference lakes.
2. To document changes in phytoplankton related to changes in acidification and trophic status.

Background:

The biomass and species composition of the phytoplankton of dilute, nutrient-poor, acid stressed lakes is typically very different from that of more alkaline lakes. Some indicator species or associations of species have been identified as strong indicators of acid stressed lakes. Because phytoplankton species form the base of aquatic food webs, and because some species are more "food-web functional" than others, lake acidification and lake neutralization can have important ecological effects on communities of higher organisms (e.g. fish) through alterations of the phytoplankton community. Effects may also be more directly demonstrated as changes in occurrence of certain bloom-forming or odour producing species.

Project Description:

Regular collections of phytoplankton from several Muskoka-Haliburton-Sudbury area lakes (by Dorset and Northeastern Region staff). Some analyses are done on pooled samples to reduce analysis costs.

Product:

Technical reports and scientific publications on long term trends related to acidification abatement.

Publications/Reports/Presentations:

1. Can. J. Fish. Aquat. Sci. (1990), 47: 422-431.

Application of Results:

The results will be used to ecosystem damage from acid rain and recovery from SO_2 emission controls.

TASK 2

AQUATIC EFFECTS

CHEMICAL STUDIES

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Deposition of ions and nutrients in Muskoka-Haliburton.

Project Leader:

P. Dillon

Purpose:

To quantify the atmospheric bulk deposition of ions (NO_3, NH_4, SO_4, Cl, Ca, Mg, Na, K, H) and nutrients (phosphorus, nitrogen) to catchments and lakes in Muskoka-Haliburton.

Background:

In order to determine the effects of acid deposition on the aquatic environment, measurement of the deposition of sulphates and other ions to the lakes and streams in the Muskoka-Haliburton area is needed on a long-term basis.

Project Description:

Bulk collectors have been used for rain and snow collection at a variable number of sites in Muskoka-Haliburton since 1976. Currently, four sites are employed (Plastic Lake, Dorset Research Centre, Heney Lake and Harp Lake). A meteorological data base for the region is also maintained. Organization of a meteorological data base using data base management software (ORACLE) was initiated.

Product:

To date, it has been determined that precipitation chemistry in Muskoka-Haliburton is dominated by the strong acids, H_2SO_4 and HNO_3, with a significant amount of NH_4. The SO_4/NO_3 ratio, averaging 2:1 on an annual basis, 1:1 during winter, and 3:1 during summer, is dropping as S emissions decrease. SO_4 concentration decreased in the period 1979 to 1986 as a result of decreases in SO_2 emissions; as SO_4 deposition declined, the importance of NO_3 deposition has increased. Analysis of trends in deposition data indicates that a trend to

decreasing concentrations of SO_4 and H has stopped, deposition has been virtually constant since 1987.

Application of Results:

Results are used in monitoring the effects of the Canadian and U.S. acid rain control programs.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Long-term trends in aquatic chemistry.

Project Leader:

P. Dillon

Purpose:

To measure the changes in lake, stream and lake sediment chemistry that result from atmospheric deposition of strong acids, ions and trace metals.

Background:

Measurement of changes in water chemistry will allow prediction of the rate of acidification and provide valuable information for developing and implementing emission reduction strategies.

Project Description:

A set of 20 streams and 8 lakes in Muskoka-Haliburton have been monitored for durations ranging from 8-13 years. An additional 40 lakes are sampled on a less frequent basis. We are attempting to measure long-term effects of acidic deposition on the chemistry and biology of these waters. A set of 4 lakes near Sudbury that were extensively studied in the 1970s are also monitored regularly. These data are also used to develop and test chemical models for prediction of the effects of acid deposition.

Analysis of trends in stream chemistry has been carried out. The analysis of trends in lake chemistry of the secondary lakes is underway to determine if the major study lakes' behaviour is typical. Extrapolation to the provincial and sensitivity survey database will follow.

Trends in lakes near Sudbury, where deposition of S has decreased substantially, have levelled off in the last few years.

Product:

This study has provided us with rate of change of lake chemistry as a function of atmospheric deposition for a set of lakes in south-central Ontario. It will also provide the means to extrapolate long-term changes province-wide.

Publications/Reports/Presentations:

Girard, R. and R.A. Reid. 1990. Morphometric and geological data for nineteen lakes in the Parry Sound and Nipissing District and Haliburton County. Ont. Min. Envir. Data Report DR 90/2.

Girard R. and R.A. Reid. 1990. Dorset Research Centre Study Lakes: Sampling methodology (1986-1989) and lake morphometry. Ont. Min. Environ. Data Report DR 90/4.

Scholer, P.J., P.J. Dillon, B.D. LaZerte and K. Devito. 1990. Survey design for assessing the sensitivity of lakes to acid deposition. Ont. Min. Envir. Tech. Rep. 152 pp.

Application of Results:

Results have been used in negotiations with the U.S. for sulphur emission controls and subsequently needed to monitor the benefits of the control programs and to determine if the target loadings need to be refined.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Lake and watershed mass balances.

Project Leader:

P. Dillon

Purpose:

To determine quantitatively the inputs of substances to the study lakes and watersheds and the chemical response of the lakes and streams, so that prediction of the effects of changes in input rates can be made; to determine the relative importance of the different sources of alkalinity to lakes; to determine the fate of sulphate deposited on lakes and catchments.

Background:

Documented evidence of the impact of acid deposition on selected chemical characteristics of aquatic ecosystems is an important component of Ontario's case for emission reductions. It will also provide information for the development and refinement of target loadings.

Project Description:

Mass balances of important chemical substances (strong acids, alkalinity, nutrients, base cations, etc.) have been measured for approximately 20 catchments and 8 lakes for periods ranging from 8-13 years. These data are the basis for modelling the relationships between environmental stresses (e.g. acidic deposition) and the chemical and biological response of the lakes and streams, and for determining acceptable levels of environmental stress.

In 1989-90, analysis of catchment yields of SO_4 and base cations for the Plastic Lake system was completed; long-term trends in mass balances were compared to trends in deposition rates, indicating that catchment response to changes in S deposition was relatively rapid.

Carbon budgets for Plastic and Harp lake were completed, demonstrating the role of the lakes as dissolved organic carbon (DOC) sinks and CO_2 sources.

Product:

Mass balance measurements demonstrated that in-lake production of alkalinity by sulphate reduction, denitrification, organic acid protonation and ion exchange was at least as important as external sources to the lakes' overall alkalinity budgets. Sulphate is stored in specific portions of the study watersheds, e.g. bogs, that experience reducing conditions for at least part of the year, but the SO_4 can be released in large quantities following re-oxidation in dry periods. In the long-term however, there appears to be no net storage of sulphate in the catchments. The catchments are sources of base cations, while the lakes are conservative with respect to base cations. Additional chemical responses will be assessed and provide input to the modelling project.

Application of Results:

The results are used to monitor the effects of the Canadian and U.S. acid rain control programs.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Modelling the effects of acidic deposition on lake and stream chemistry.

Project Leader:

P. Dillon

Purpose:

To develop, test and utilize mathematical models relating the deposition of strong acids to lake and stream chemistry; to develop methodologies for assessing the performance of these models.

Background:

These models are needed to assist in determining the benefits of various emission control strategies in both Canada and the U.S.A.

Project Description:

Data collected as part of the lake and watershed mass balance project have been used to develop, calibrate and confirm several models. A lake model (FLASCH) has been utilized for sulphate, phosphorus and base cations. The Birkenes-Storgama chemistry model developed for Norwegian streams by Seip and Christophersen was calibrated for several of the Harp Lake inflows and has been employed in making predictions about the effects of changes in S deposition on the chemistry of other Harp inflows. Recent progress made in model development has resulted in a proposal to modify the hydrologic component of the model. Furthermore, scientific groups in Norway, Great Britain, Canada, and the U.S.A. are co-operating on further model development and applying the model to catchments in their countries. The MAGIC model has been implemented for Plastic Lake, and the results compared to long-term changes in the lake and catchment, and to independent estimates of weathering rates.

Product:

These models can be used both as investigative tools and as predictive tools. As investigative tools, they can be used to examine the efficacy of scientific concepts about the systems being modelled. As predictive tools, they can be used to predict changes in parameters, such as alkalinity, pH, Ca and SO_4 under current loadings or under different scenarios of increased or decreased loadings. As additional data become available, these models are refined in order to improve their accuracy in prediction.

Publications/Reports/Presentations:

Locke, B.A. 1990. Quality control data report for the Limnology Section, Dorset Research Centre, Ont. Min. Envir. Data Report DR 90/3.

External Co-operation:

J. Cosby (Duke University), R. Wright (Norwegian Institute for Water Research)
J. Kirchner (University of California at Berkeley)
J. Davis (Electric Power Research Institute)
D. Lam. G. Bobba (NWRI, Environment Canada)
H.M. Seip, N. Christophersen (CIIR, Oslo, Norway)

Application of Results:

Used to assess the benefits of abatement programs.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Alkalinity surveys of lakes in central Ontario.

Project Leader:

B. Neary

Purpose:

To assess the degree of acidification of lakes in central Ontario. To determine whether the acid buffering status of lakes in central Ontario has changed with time.

Background:

Work is underway to determine the acidification status of lakes across Ontario. Certain geographic areas and lake sizes are under-represented in the current data base. These data deficiencies have been identified and will be addressed through the collection of lake water chemistry data. Trends in alkalinity, on a lake population basis, will be determined by resampling lakes which were sampled a number of years ago.

Project Description:

Data on lakes which have not been sampled so far will be incorporated into the Inland Lakes Database. Projections from available data will then be made to the estimates of the total number of lakes in areas of Ontario receiving significant amounts of acid deposition, providing reasonably accurate projections of the size of the aquatic resource adversely affected by acidification. The resampling of lakes will permit statements on whether the acid neutralizing status of sensitive lakes in Ontario is changing appreciably.

Product:

Estimates of the number of affected lakes in areas of Ontario receiving acid deposition.

Publications/Reports/Presentations:

Neary, B.P., P.J. Dillon, J.R. Munro and B.J. Clark. 1990. The acidification of Ontario lakes: an assessment of their sensitivity and current status with respect to biological damage. Ont. Min. of Envir. Technical Report, January 1990.

Scholer, P.J., P.J. Dillon, B.D. LaZerte and K. Devito. 1990. Survey design for assessing the sensitivity of lakes to acid deposition. Ont. Min. Envir. Technical Report.

Application of Results:

Results are used to produce the Acid Sensitivity Survey document. Data are also valuable for assessing the impact of other environmental problems. An example is the use of lake chemistry data to synthesize maps of the probability of zebra mussel invassion into inland lakes in Ontario.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Chemical fluxes and neutralization processes in stream courses.

Project Leader:

P. Dillon/B. LaZerte

Purpose:

To measure the changes in stream chemistry in Harp Inflow #4 and Plastic Inflow #1 from the stream sources, in order that the processes that control the neutralization rate of acid deposited from the atmosphere can be determined. The role of wetlands and the influence of groundwater will be evaluated.

Background:

Most of the strong acid deposited on catchments in Muskoka/Haliburton is neutralized but the mechanisms and rates are not understood. These data are essential for model development and for understanding the response of catchments to the decreasing acid deposition expected to result from the Countdown Acid Rain Programme.

Project Description:

The chemistry of the streamwater is being monitored at a number of sites in each of the Harp #4 and Plastic #1 inflows. The nitrogen and phosphorus fluxes in these catchments have been investigated and the importance of wetlands as transformers of both to organic forms documented.

Product:

The processes that control the neutralization rate of acid deposited from the atmosphere will be determined. The importance of groundwater in catchments with deep till will be assessed, as will the importance of wetlands as sources/sinks for acid, S, trace metals, cations, etc.

Publications/Reports/Presentations:

Schiff, S., R. Aravera, S. Trumbore and P.J. Dillon. 1990. Contribution of carbon isotopes to the understanding of the cycle of dissolved organic carbon in forested watersheds. Water Resources Res. (in press).

Wels, C., J. Cornett and B.D. LaZerte. 1990. Hydrograph separation using geochemical tracers. J. Hydrol. (in press).

Wels, C., R.J. Cornett and B.D. LaZerte. 1990. Relationships of stream solutes and hydrology during spring runoff in small shield headwater streams. Ministry of the Environment Tech. Report.

Wels, C., C. Taylor, R. Cornett and B.D. LaZerte. 1990. Stream flow generation in headwater basins on the Canadian Shield. Hydrol. Proc. (in press).

Dankevy, S. 1990. Groundwater flow and chemistry in a small acid-stressed subcatchment of the Canadian Shield. B.Sc. Thesis. University of Western Ontario, London, Ontario.

Dillon, P.J. and B.D. LaZerte. 1990. Response of the Plastic Lake catchment, Ontario to reduced sulphur deposition. Environmental Pollution (submitted).

External Co-operation:

S. Schiff - Waterloo University
M. English - Wilfred Laurier University

Application of Results:

The results will be used in determining the effects of the sulphur control programs. The methodologies developed for this project will be useful in the future for evaluating trace metal and other contaminant fluxes.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Trace metal cycling in calibrated watersheds.

Project Leader:

B. LaZerte

Purpose:

To determine the major sources and sinks of cadmium (Cd), lead (Pb), copper (Cu) and zinc (Zn) in the calibrated catchments and lakes that we are currently studying in Muskoka.

Background:

Acidification is accompanied by elevated concentrations of some trace metals, which can adversely affect biota. Some of the metals are mobilized from the catchment by acid deposition; others are transported concurrently with the strong acid in precipitation.

Project Description:

At present, we are monitoring precipitation inputs, soil water seeps, lake inputs and outflows. Methodologies are of almost sufficient sensitivity to monitor ambient levels. A few improvements are being implemented to increase sensitivity down to the ng/L range. Field sampling techniques have been revised and are of sufficient cleanliness to eliminate contamination problems. Data collection will continue at all sites with expansion to Dorset lysimeter samples.

Product:

An interim assessment indicates that uplands soils are major sinks for Cu and Pb. Conversely, acidification releases Zn from the soils. Zinc may be stripped from the organic layer of soils. Wetlands appear to export Cu and Pb, probably as organic complexes.

Publications/Reports/Presentations:

Bendell-Young, L.I., H.H. Harvey, P.J. Dillon and P.J. Scholer. 1990. Contrasting behaviour of manganese in the surficial sediments of 13 south-central Ontario lakes. Sci. Tot. Envir. (in press).

Norton, S.A., P.J. Dillon, R.D. Evans, G. Mierle and J.S. Kahl. 1990. The history of atmospheric deposition of Cd, Hg and Pb in North America: evidence from lake and peat bog sediments. In S.E. Lindberg, A.L. Page and S.A. Norton, eds. Sources, Deposition and Canopy Interactions Vol. III Acidic Precipitation, Springer Verlga, New York, N.Y. pp. 73-102.

Dillon, P.J. and B.D. LaZerte. 1990. Response to the Plastic Lake catchment, Ontario to reduced sulphur deposition. Environ. Pollut. (in press).

LaZerte, B.D. and K. Burling. 1990. Manganese speciation in dilute waters in the Precambrian shield, Canada. Water Res. 24: 1097-1101.

Application of Results:

The results will be used in monitoring the effects of the Canadian and U.S. sulphur control programs.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Bioaccumulation of nutrients by upland forest ecosystems.

Project Leader:

B. LaZerte

Purpose:

To quantify the contribution of the uptake of minerals (especially base cations) by forest growth to the acid budget of the soil and soil-water solutions.

Background:

Growing forests have been shown to be important acidifiers of terrestrial catchments. It is important to separate the effects of forest growth versus anthropogenic acid deposition.

Project Description:

The standing crop and annual increment of basic cations (nitrogen (N), sulphur (S) and aluminum (Al)) in the upland forests ecosystem including major tree species, litter and organic soil components will be measured for the Harp, Plastic and Hawkeye Lake study areas.

Using these data, the rate of proton production by forest growth will be calculated from the net difference in anion and cation assimilation and compared to rates of proton loading by atmospheric deposition, and proton consumption of abiotic soil processes. The standing crop measurements will then be compared between stands, with other forest stands in different deposition zones, with known nutritional requirements of the major tree species, and with soil content and availability (see weathering and sulphur projects).

Product:

Preliminary standing crop reports are available for the High Falls site. On a weight basis, this catchment is highly depleted in sulphur and potassium with respect to a Hubbard Brook, New Hampshire study. A final report will be completed by 1991.

Application of Results:

The data for this study will be used in the soils catchment acidification models developed under other projects.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Soil/soil water interactions.

Project Leader:

B. LaZerte

Purpose:

1. To measure the input, export and internal cycling of nutrients including sulphur (S and metals in forested ecosystems.
2. To investigate the interaction between deposition, vegetation, soils, groundwater and streamwater.
3. To characterize the degree, forms and mechanisms of sulphur storage in the soil, to examine S storage capacity, release and uptake in the Plastic and Harp Lake soils.

Background:

Routine monitoring at the Harp and Plastic Lake sites includes precipitation, groundwater, soilwater and streamwater. The Harp and Plastic Lake sites in southern Ontario were established in 1981 whereas monitoring at the Hawkeye Lake site in northwestern Ontario started in 1982, and was terminated at the beginning of FY 1989-90.

Project Description:

Soil water monitoring by horizon with zero tension lysimeters and tension lysimeters and monitoring of streams and deep groundwater is performed at Plastic and Harp Lakes. Lysimeter data will be related to the stream chemistry data. As most neutralization of acidic deposition occurs in the soils, knowing the major processes occurring in the soils, and their rates is very important.

Soils have also been sampled from the catchments and analyzed for about 23 different parameters. Laboratory experiments were performed on the soils to determine sulphur

binding processes and their importance by horizon, sulphur species present and aluminum leaching from the soils.

Product:

Data from these monitoring sites will be used in a long-term catchment acidification model, in related biogeochemistry project reports and for estimation of critical S load to soils.

The major difference in stream chemistry between Plastic and Harp Lake catchments is accounted for by the long residence time of the groundwater at Harp Lake. Harp soil solutions have a greater pH and alkalinity than Plastic lake soil solutions, however, base cation concentrations are similar. Sulphate is higher at Plastic Lake. These findings confirm that differences in pH and alkalinity of the soil drainage waters are due to differences in aluminum and sulphate released from the soils, not base cation release.

The presence of hydroxy-interlayered vermiculite may account for the strong uptake of base cations seen in the B horizons of the soils. Preliminary studies have shown allophane to be the major amorphous aluminum-silica (Al-S); compound in the soils. Soil solution concentrations of Al and Si agree with this hypothesis.

Application of Results:

These results will be used in monitoring the effects of the Canadian and U.S. sulphur control programs and for estimation of critical sulphur load to soils.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Natural mineral weathering rates of bedrock and till on the Precambrian Shield and how they are affected by acidic deposition.

Project Leader:

B. LaZerte

Purpose:

1. To identify the important weathering reactions that occur within a catchment and to determine the catchment-wide rates of these reactions.
2. To evaluate the effects of strong, weak and complex organic acids on the nature and rate of weathering of minerals and relate the reactions to runoff water compositions of local and regional catchments.
3. To produce a kinetic-thermodynamic model for weathering of minerals and rocks.

Background:

This project will assist in defining the interactions between various components of the terrestrial system and components of the aquatic system.

Project Description:

The first goal will involve four phases:
- identification of weathering reactions in the catchment;
- major element mass balances and rates of reaction;
- behaviour of trace elements in the catchment;
- surface studies.

The second goal will be achieved by:
- experimental studies with strong, weak and organic acids;
- comparative study of catchment waters and experiments.

A kinetic-thermodynamic model will be developed to simulate weathering of minerals and rocks in different environmental settings and under different physical and chemical conditions.

Product:

Major achievements for FY 1990-91 include:

Paper on "Experimental studies on weathering rates under different acidic conditions".

Integration of these results into an overall catchment weathering model.

Publications/Reports/Presentations:

Kettlewell, D. 1990. Weathering processes within a soil profile from the Harp Lake catchment, Ontario. B.Sc. Thesis, University of Western Ontario, London, Ontario.

Nesbitt, H., N. MacRae and W. Shotyk. 1990. Congruent and incongruent dissolution of labradorite in dilute, acidic salt solutions. Geochimica Cosmocima Acta (in press).

Rasmussen, P., S. Schiff and W. Nesbitt. 1990. The determination of exchangeable cations in acid soils: errors caused by dissolution of the exchange substrate during neutral salt extraction. Can. J. Soil. Sci. (submitted).

External Co-operation:

The study is being conducted by Prof. Nesbitt at the University of Western Ontario (London).

Application of Results:

These mineral weathering results are used in models of long-term changes in stream chemistry to determine the rate of acidification in the Muskoka-Haliburton area.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

The impact of increased sulphur deposition on the sulphur cycle of upland forest ecosystems.

Project Leader:

A. Neary (LSB)

Purpose:

1. To determine to what extent sulphate adsorbed to soil iron (Fe) and aluminum (Al) oxides is a major sink in upland forest soils, and to what extent this sulphate is 'specifically' adsorbed.
2. To determine to what extent sulphate is incorporated into upland forest biomass (see Bioaccumulation project) relative to that adsorbed in the mineral fraction (1) of upland forest soils.
3. To determine the saturated sulphate retention capacity.
4. To determine effective rate constants for catchment sulphur uptake and release as a function of deposition rates.
5. To determine to what extent mineral weathering is releasing authigenic sulphur as sulphide (see Mineral Weathering project).

Background:

Information on the sulphur cycle is key to both the aquatic and biogeochemistry components of the APIOS programme.

Project Description:

Laboratory experiments are used to determine the important sulphur binding processes and their rates in natural soils.

Product:

Previous studies indicate that water soluble sulphate is found mostly in the upper organic horizons, whereas adsorbed sulphate is primarily in the B horizons. Effective rate constants for catchment sulphur uptake and release as a function of deposition rates will be used in the long-term catchment acidification model.

Publications/Reports/Presentations:

Hern, J. 1990. Influence of soil sulphate adsorption on lake acidification. Verh. Verein. Internat. Limnol. (submitted).

Hern, J. 1990. An investigation of the sulphur status of Plastic Lake soil. Final report to the Ministry of the Environment.

External Co-operation:

J. Hern (Trent University)

Application of Results:

Results will be input into the long-term catchment acidification model used to determine the rate of acidification in the Muskoka-Halibuton area and to evaluate the effects of various abatement programs.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

The role of wetlands in chemical cycles.

Project Leader:

P. Dillon

Purpose:

To evaluate the role of wetlands in modifying the acid, sulphur and base cation cycle of catchments.

Background:

Wetlands, which are ubiquitous in Precambrian catchments, can act as sulphur (S), nitrogen (N) and cation sinks. This may result in delayed recovery of aquatic systems following S emission reductions. The Plastic Lake catchment now appears to be releasing some of the sulphur that was stored earlier and "altering" the chemistry of downstream waters accordingly. The wetlands are also a source of dissolved organic carbon (DOC), which controls the natural organic acidity of surface waters.

Project Description:

The research will focus on catchment/wetland systems for which we already have an extensive database. These include the Sphagnum-conifer swamp at Plastic Inflow #1 and the beaver pond and sedge fens at Harp Lake Inflow #4. The processes that control S fluxes will be investigated, and measures of the S pools in the wetlands and their depletion rates developed. The role of wetlands as methane producers will also be evaluated.

Product:

The results of the S-cycle work will contribute to the modelling work on lake response to S and N emission reductions.

Publications/Reports/Presentations:

Devito, K. and P.J. Dillon. 1990. The influence of hydrology on nitrogen retention in a Sphagnum-conifer peatland on the Canadian Shield. Abstracts ASLP, annual meeting, Williamsburg, Virginia, June 1990, p. 24.

External Co-operation:

Most of the work will be conducted by external research associates at universities including N. Roulet/K. Devito (York University) and J. Cornett/C. Wehenmeyer (Trent University).

Application of Results:

These results will be used to determine the effects on lake response of the Canadian and U.S. acid rain control programs.

LIMNOLOGY SECTION
WATER RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Watershed manipulation experiments.

Project Leader:

P. Dillon

Purpose:

To continue to cooperate and co-fund external agencies conducting watershed manipulation experiments to determine critical loads to terrestrial catchments.

Background:

The Ministry of the Environment has been funding the RAIN (Reversing Acidification in Norway) watershed manipulation experiments since 1982. The objective of the RAIN project is to determine the rate of response of the chemistry of runoff water from small catchments to changes in loading of strong acid from the atmosphere. To date, the chemical study results appear to indicate that acidification is reversible. Much of our interest in the RAIN project is based on the belief that the results of the study can be extrapolated to the Canadian environment. However, since there are some significant differences between the experimental RAIN catchments and sensitive Canadian catchments, from FY 1987/88, we have been providing funding to assist the Department of Fisheries and Oceans in their experimental acidification of a catchment in the Experimental Lakes Area (ELA).

Project Description:

The Ministry of the Environment plans to continue to fund the ELA project. The data from the study will be useful for the final interpretation of our results and for extrapolation from the RAIN project to Ontario.

Product:

These studies will provide us with critical load estimates for terrestrial catchments. They have already been extensively useful because they have provided irrefutable proof of the reversibility of catchment acidification, thus supporting the emission control programme.

Publications/Reports/Presentations:

Wright, R.F., B.J. Cosby, M.B. Flaten and J.O. Reuss. 1990. Evaluation of an acidification model with data from manipulated catchments in Norway. Nature. 343: 53-55.

External Co-operation:

R. Wright (Norwegian Institute for Water Research)
R. Heckie/C. Allan (Canada Department of Fisheries and Oceans)

Application of Results:

Results have supported the need for emission controls. They will also provide us with critical load estimates for terrestrial catchments.

EXPERIMENTAL LAKE NEUTRALIZATION PROGRAM
MOE/MNR
PROJECT SUMMARY: 1990-1991

Project Title:

Experimental Lake Neutralization Program.

Project Leader:

W. Keller

Purpose:

To investigate the feasibility of using neutralization to protect and rehabilitate acid sensitive and fully acidic Ontario lakes.

Background:

This inter-agency program was initiated to provide natural resource managers with information regarding the potential usefulness of neutralization as a management technique, while negotiations for reductions in acidic deposition continued and control technology was developed. Neutralization is considered only a temporary measure, because it alleviates the symptoms of the problem but does not eliminate the cause. It was felt, however, that interim methods of mitigating the effects of acidification on aquatic resources should be assessed, and lake neutralization did hold promise for some situations.

Project Description:

Intensive monitoring commenced on one fully acidified lake (Bowland Lake; 47°40'N, 80°50'W) and two lakes sensitive to acidification (Trout Lake: 45°35'N, 80°10'W; Miskokway Lake; 45°40'N, 80°14'W) in the spring of 1982. Bowland Lake had historically supported a lake trout (*Salvelinus namaycush*) population that had become extinct, leaving a fish community comprised of abundant acid-tolerant yellow perch (*Perca flavescens*). Trout and Miskokway lakes continued to support lake trout populations as well as populations of other sportfish and forage fish species.

Bowland and Trout lakes were ultimately selected as the final candidates for neutralization. Bowland lake was neutralized in August 1983 and Trout Lake in May 1984. Because both lakes were remote, it was most cost effective to treat them with finely powered limestone

($CaCO_3$) dropped from a fixed wing air-craft. Long term post-neutralization patterns in the chemistry and biological communities (fish, plankton, benthos) were examined up to 1990.

Product:

Findings of the study were encouraging. Neutralization increased the pH and alkalinity of Trout Lake, without causing damage to the existing aquatic communities. Improved growth of lake trout in the lake appeared to be related to increased abundance of Mysis, a favoured prey item, after neutralization. Whole-lake neutralization was also effective in increasing the pH and alkalinity of Bowland Lake to levels typical of dilute Precambrian Shield lakes, although reacidification, inevitably, increased lake acidity during the post neutralization period. Reacidification patterns generally followed patterns of water replenishment time. After neutralization, surface water pH depressions asssociated with acidic spring runoff continued. However, despite the continuance of these acid episodes, improved whole-lake water quality did allow reestablishment of a lake trout population in Bowland Lake, and ultimately, successful reproduction by the introduced lake trout.

Other aquatic trophic levels generally showed either positive responses or a lack of response to the neutralization of Bowland Lake. The phytoplankton community of the lake changed from dominance by blue-greens to dominance by other taxa, particularly chrysophytes, a more natural condition for oligotrophic Precambrian Shield lakes. Zooplankton community composition also shifted to a structure more typical of non-acidic lakes, but recovery was not complete by the time lake reacidification again began to affect the plankton community. No substantial effects on the plankton community of Trout Lake, related to the neutralization, were observed. Aquatic macrophytes were not measurably affected by neutralization; however, profuse benthic growths of filamentous algae were rapidly eliminated, then began to reestablish very early during the reacidification of Bowland Lake.

Not all biological changes after neutralization could be directly attributed to altered chemistry. Patterns in the abundance, biomass, and size structure of zoobenthos were closely linked to changes in the fish community. Zoobenthos surveys also demonstrated that even after restoration of suitable water quality, recovery of natural zoobenthos community composition may be a slow process, since many acid sensitive taxa were still absent from Bowland Lake 2 years after neutralization. Significant increases in the diversity of zoobenthos communities did, however, occur after neutralization.

Application of Results:

Overall, this study has developed suitable techniques for the neutralization of remote acidified or acid sensitive lakes. No significant adverse impacts of the treatments were observed, and positive responses did occur among various aquatic trophic levels. While neutralization is obviously not a general solution to the lake acidification problem in Ontario, it is technically feasible in many situations, and does provide a management option that can be expected to provide substantial biological benefits in some cases. 1990-91 was the last year of this study.

Publications/Reports/Presentations:

Gunn, J. M., J. G. Hamilton, G. M. Booth, G. L. Beggs, C. D. Wren, H. J. Rietveld, and J. R. Munro. 1990. Survival, growth and reproduction of lake trout (*Salvelinus namayeush*) and yellow perch (*Perca flavescens*) after neutralization of an acidic lake near Sudbury, Ontario. Can. J. Fish. Aquat. Sci. 47:446-453.

Jackson, M. B., E. M. Vandermeer, N. Lester, J. Booth, L. A. Molot, and I. Gray. 1990. Effects of neutralization and early reacidification on filamentous algae and macrophytes in Bowland Lake. Can. J. Fish. Aquat. Sci. 47:432-439.

Keller, W., L. A. Molot, R. W. Griffiths, and N. D. Yan. 1990. Changes in the zoobenthos community of acidified Bowland Lake after whole-lake neutralization and lake trout (*Salvelinus namaycush*) reintroduction. Can. J. Fish. Aquat. Sci. 47:440-445.

Keller, W., D. P. Dodge, and G. M. Booth. 1990. Experimental Lake Neutralization Program: an overview of neutralization studies in Ontario. Can. J. Fish. Aquat. Sci. 47:410-411.

Molot, L. A., P. J. Dillon, and G. M. Booth. 1990. Whole-lake and near-shore water chemistry in Bowland Lake, before and after treatment with $CaCO_3$. Can. J. Fish. Aquat. Sci. 47:422-431.

Molot, L. A., L. Heintsch, and K. H. Nicholls. 1990. Response of phytoplankton in acidic lakes in Ontario to whole-lake neutralization. Can. J. Fish. Aquat. Sci. 47:412-421.

Keller, W., N. D. Yan, T. Howell, L. A. Molot, and W. D. Taylor. 19__. Responses of zooplankton to the experimental neutralization and early reacidification of Bowland Lake near Sudbury, Ontario. Can. J. Fish. Aquat. Sci. (under review).

Booth, G. M., C. D. Wren, and J. M. Gunn. 19___. The efficacy of shoal liming for rehabilitation of Lake Trout (*Salvelinus namaycush*) populations in acid stressed lakes. N. Am. J. Fish. Mgmt. (under review).

Howell, E. T., G. Coker, G. M. Booth, W. Keller, B. Neary, K. Nicholls, F. D. Tomassini, N. Yan, J. Gunn, H. Rietveld, and D. Wales. 19__. Ecosystem responses of a pH 5.9 lake trout lake to whole-lake liming. Lake and Reserv. Mgmt. (under review).

BAR Environmental. 19___. Experimental Neutralization Ten Year Technical report. Vols 1 and 2 (in prep.).

External Cooperation:

The study was coordinated by B.A.R. Environmental. Various subcontractors including university and private sector participants were involved.

SPECIAL STUDIES UNIT
NORTHEASTERN REGION
PROJECT SUMMARY: 1990-1991

Project Title:

Long-term Acidification Monitoring of Northeastern Region Lakes.

Project Leader:

W. Keller

Purpose:

To assess long-term patterns in the chemical and biological status of lakes in northeastern Ontario, related to deposition of acids and metals from regional and long range sources.

Background:

Following the initial documentation, in the 1970's, of widespread effects of acidification in northeastern Ontario lakes, various lake monitoring programs were initiated. Originally, efforts focused on assessing the extent of chemical and biological damage due to chronic and episodic acidification. Estimates of damage, based on survey data, revealed that the majority of acidic lakes in Ontario are located within the Northeastern Region, and a very high proportion of these are affected by emissions from the Sudbury Smelters.

With recent findings that decreases in Sudbury smelter emissions have resulted in improved water quality in many Sudbury area lakes, emphasis has shifted toward monitoring long-term chemical and biological trends in regional lakes in order to permit assessment of the adequacy of control measures, and to develop an understanding of how lakes will respond to decreased acid loadings. Observations of lake recovery in the Sudbury area to date have provided great support for source control strategies.

Project Description:

Various levels of lake monitoring are being conducted in northeastern Ontario. Efforts include 1) once annual chemistry sampling of 45 acidic lakes within 120 km of Sudbury 2) monthly or twice monthly chemical and biological sampling of 6 lakes on a continuing basis, and 3) monthly chemical and biological sampling of 5 lakes, with intervals of ~5 years between study periods. Chemical sampling routinely includes assessment of acidity, major

ions, nutrients and trace metals. Biological sampling routinely includes collection of zooplankton and phytoplankton samples. In some lakes, periodic surveys of benthic invertebrate communities are conducted.

Product:

Aquatic surveys in the Northeastern Region have provided major contributions to the provincial lake sensitivity data base. Studies, particularly in the Sudbury area, have been instrumental in developing our understanding of the chemical and biological responses of aquatic systems to acidification, as reflected by the large number of Sudbury related publications in the scientific literature.

An effort is currently being coordinated by MOE to compile a multi-agency, multidisciplinary, series of papers for publication as a set in a high quality journal. This should provide an excellent summary of the current status of the lakes, and will establish an important framework for examining data from future studies.

Current field efforts focus on documenting actual chemical and biological responses of aquatic systems to reductions in sulphur and metal deposition. Evaluation of responses, and documentation of real benefits is essential to demonstrate the worth of source abatement strategies and to determine additional abatement measures required. In particular, monitoring programs will focus on evaluating the effects of the Countdown strategy, on regional lake water quality.

Application of Results:

Studies in the Sudbury area have made substantial contributions to developing our understanding of the acid deposition problem. The monitoring programs that have been established will allow evaluation of the response of lakes to emission controls and will permit assessment of additional abatement measures needed.

Publications/Reports/Presentations:

Yan, N. D., W. Keller, H. J. MacIsaac and L. J. McEachern. 1990. Regulation of zooplankton community structure of an acidified lake by *Chaoborus*. Ecol. Appl. 1:52-65.

Keller, W., N. D. Yan, K. Holtze and J. R. Pitblado. 1990. Inferred effects of lake acidification on *Daphnia galeata mendotae*. Environ. Sci. Tech. 24:1259-1261.

Gunn, J. M. and W. Keller. 1990. Biological recovery of an acid lake after reductions in industrial emissions of Sulphur. Nature (London). 345:431-433.

Keller, W. and N. D. Yan. 1991. Recovery of crustacean zooplankton species richness in Sudbury area lakes following water quality improvements. Can. J. Fish. Aquat. Sci. (in press).

Keller, W. and J. M. Gunn. 19___. Whitepine Lake. In Data Book of World Lake Environments. International Lake Environment Committee, Otsu, Japan (in press).

Keller, W., J. M. Gunn and N. D. Yan. 19___. Evidence of biological recovery of acid stressed lakes near Sudbury, Canada. Environ. Poll. (in press).

Keller, W., J. R. Pitblado and J. Carbone. 19___. Long-term chemical responses of acidic lakes in the Sudbury, Ontario area to reduced smelter emissions. Can. J. Fish. Aquat. Sci. (under review).

Vandermeulen, H., M. B. Jackson, A. Rodrigues and W. Keller. 19___. Filamentous algal communities in Sudbury area lakes: effects of variable lake acidity. Can. J. Fish. Aquat. Sci. (under review).

Griffiths, R. W. and W. Keller. 19___. The response of the benthic macroinvertebrate fauna in three lake basins to a reduction in acid deposition. Can. J. Fish. Aquat. Sci. (under review).

External Cooperation:

Much of this work is conducted in close cooperation with other government agencies and universities, in particular the Ontario Ministry of Natural Resources and Laurentian University.

TASK 3

TERRESTRIAL EFFECTS

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Survey of hardwood decline in Ontario

Project Leader:

W.D. McIlveen

Purpose:

To document the condition of hardwood forests in Ontario with respect to potential effects of long-range transported pollutants.

Background:

Dieback and decline of forest trees has been reported in Ontario. The cause of this problem has been attributed to acidic precipitation. The extent and severity of the problem requires documentation as does the potential temporal change. To obtain the required information, a network of permanent observation plots was established across the province.

Project Description:

Quantitative assessments of tree condition at 110 plots in the Great Lakes - St. Lawrence and Deciduous Forest Regions were conducted in 1986, 1987, 1989 and 1990. Site quality and soil properties also were recorded. Samples of foliage from sugar maple and yellow birch as well as soil samples for chemical analysis were collected from selected plots.

Product:

The 1986 survey identified regional differences in the condition of hardwood trees. The greatest frequency of declining trees occurred in the Muskoka, Haliburton and Parry Sound areas. While sugar maple was the dominant species in the survey, decline symptoms of greater severity were identified on other species. Subsequent surveys identified small changes in the condition of the trees on the plots. Some changes were possibly related to defoliation by insects. In 1990, slight changes in dieback were noted with about 15% of plots showing some deterioration from previous years. Most plots stayed the same or improved slightly.

Neither soils nor foliage samples showed signs of marked nutrient imbalances or deficiencies. Higher concentrations of aluminum were found in foliage from the south western part of the province which is subjected to the heaviest acidic deposition load. There are an number of

correlations between vegetation and soil chemistry or texture. Low pH soils have higher Al and foliage in such soils have lower Ca and Mg. Increases in decline index were correlated with lower soil pH and higher foliar Mn.

Application of Results:

The information will establish the present condition of maple forests in the province as a baseline for determining whether there are regional differences in the condition of the trees over time. Any changes in forest condition over the monitoring period will aid in determining the severity, distribution and cause of a problem. This information serve as a foundation for regulatory strategies required by environmental managers.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Sugar maple decline in Ontario

Project Leader:

W.D. McIlveen

Purpose:

The objectives of the study were to establish a series of permanent observation plots in maple forest stands and use these plots to: i) develop a tree decline rating system, ii) determine causal agent(s) of sugar maple decline at selected sites and iii) determine the role of atmospheric pollutants in tree decline.

Background:

The problem of dieback of sugar maple trees initially was indicated to be most severe in the area of Muskoka. Following preliminary site visits, a project was designed to determine whether the problem was related to acidic deposition. This included a multi-year study at 7 sites in Muskoka and a control site near Thunder Bay. In 1985, the network of plots was expanded to include sites on and off the Precambrian Shield and on the Shield in areas which did not suffer insect defoliation during the 1970's.

Project Description:

In 1984, 7 plots were established in Muskoka. The total reached 11 sites in 1985. At each plot, all trees in a fixed area were identified and evaluated. Eco-physiological techniques were employed on fixed area (20 m x 20 m) plots. The trees on these plots were evaluated annually to 1990. Samples of soil, foliage, twigs and roots were collected for chemical analysis. Increment cores were taken from each tree to assess growth patterns and age. Samples from pairs of trees were collected for stem analysis of growth patterns in wood formation. The chemistry of sap samples was determined from selected trees from 1986 to 1990.

Product:

Summaries of the data received to date have been prepared. Tree condition did not change significantly at the study sites from 1984 to 1986. Tree condition deteriorated in 1987 and trees were in their poorest recorded condition in 1988. A slight recovery in condition was

noted in 1989 and they remained similar in 1989. The causes of maple decline was determined to be multifactorial and variable among sites. Among the stresses thought to be involved were climatic events, drought, insect defoliation, *Armillaria* root rot and poor woodlot management.

Application of Results:

The information derived from this project has provided considerable assistance in defining the relative importance of the various agents involved in the forest decline syndrome. Biological agents and physical environment are involved in a complex relationship which results in reduced growth, tree dieback, and tree mortality. Acidic deposition is regarded as an additional stress which accelerates the rate of the decline process.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Dendrochronology study of sugar maple

Project Leader:

W.D. McIlveen

Purpose:

To establish a growth chronology for sugar maple at selected sites in Ontario. The study was required in order to determine whether acidic precipitation and related pollutants were adversely affecting the growth of these trees.

Background:

Relative growth rates of trees are recorded as variations in widths of the annual rings. Interpretation of the growth ring patterns is known as dendrochronology and can serve as an excellent indicator of previous environmental conditions. Proper utilization of this type of information from sugar maple trees could provide a valuable addition to our knowledge of the forest in Ontario.

Project Description:

In 1985, a contract was prepared to establish sugar maple growth chronologies in the Ottawa, Algonquin and Sault Ste Marie areas. A total of 54 mature sugar maple trees were destructively sampled and about 2000 increment cores were collected from associated tree species at the study sites.

In 1989, the project was expanded to add 3 additional areas (St. Williams, Peterborough, Barrie). In combination with the previous data, these sites allowed a better coverage of the province across several pollution deposition zones. Similar sampling and measuring techniques were used.

Product:

Growth trends at the first three study sites (Ottawa, Parry Sound and Sault Ste. Marie) show increased growth patterns up to 1960. After this time, the pattern of growth showed a rapid decline to 1985 to about 50% of that for 1960. Similar patterns were observed at the later sites. A further observation was that the rate of decline in growth was greatest in the southwest where the heaviest pollution loading is typically encountered in the Province.

Application of Results:

The reduced growth rates of the study trees is strong evidence that forest productivity is being threatened. Over time, less lumber will be available to increasing demands from a growing population. This could have far-reaching implications for the future of the lumber industry in the Province of Ontario. In addition, slower growth means smaller amounts of CO_2 can be sequestered in woody material, thus reducing certain options for dealing with the climate change problem.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Statistical analysis of sugar maple tree ring growth

Project Leader:

D.L. McLaughlin

Purpose:

To develop a tree ring de-trending function for use with Ontario dendrochronological data.

Background:

Tree ring growth data have been collected for sugar maple in Ontario and a similar data set for red pine growth is currently being produced. It is not known whether existing growth models developed in other jurisdictions are applicable to the Ontario situation. An impartial statistical analysis of data for the province is required to determine the best method for interpretation of the data.

Project Description::

A grant was awarded to the University of Guelph, Department of Mathematics and Statistics, to examine the existing data set. The specific elements include the following:

1) Review of dendrochronological data with reference to tree ring de-trending functions, and categorize their efficiencies and shortcomings.
2) Review of the methodology used in sugar maple and red pine dendrochronology from a statistical perspective.
3) Development of a "made in Ontario" de-trending function for tree ring series.

The relative merits of existing models using data for Ontario will be systematically evaluated and the most appropriate model selected.

Product:

The work is progressing and model development is well under way. The most appropriate model for interpretation of future dendrochronological studies will be identified and can then be applied in any future study.

Application of Results:

This project is integral to the proper use and understanding of the tree ring data generated by the red pine and sugar maple dendrochronology studies.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Dendrochronology of red pine in Ontario

Project Leader:

D.L. McLaughlin

Purpose:

1) To determine the long term growth patterns of red pine across a pollution gradient in Ontario.
2) To determine if growth reductions have occurred in the last 10 to 25 years, and if any recent reductions are related to the pollution gradient.

Background:

Previous studies in Ontario and elsewhere in eastern North America have identified, a rapid decline in growth rate of sugar maple after 1960. It was not known whether this pattern was unique to maple or was present in other tree species as well. To determine this, growth patterns in a valuable conifer species such as red pine, was needed. Red pine has a large north-south range, less genetic variability and much narrower soil/site conditions. The study will compliment the work conducted in 1986-1990 on sugar maple.

Project Description:

Seven study areas were selected across the major pollution gradient from southwest to east in Ontario: 1) St. Williams, 2) Durham, 3) Bracebridge, 4) North Bay, 5) Pembroke, 6) Blind River, and 7) Temagami. Five plots were established in each study area, and three sub-plots composed each study plot. A single tree at the centre of each sub-plot was felled for stem analysis, and increment cores were collected from the 10 trees closest to the centre tree.

Product:

The field work of collection of samples has been completed. Measurement and interpretation of tree ring patterns is underway. A report summarizing the data with respect to the influence of environmental quality will be prepared.

Application of Results:

This project compliments the study of dendrochronology of sugar maple in that it deals with an entirely different type of tree species. The information provides data for one of the most highly managed species in Ontario and thus can be rapidly incorporated or considered in forest management plans.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Investigation of birch dieback in the Wawa area of Ontario

Project Leader:

W.D. McIlveen

Purpose:

To investigate the nature, extent and cause of dieback of white birch trees in Northern Ontario

Background:

The location of the most severe dieback of forest trees in Ontario involves an extensive area of birch trees on the east shore of Lake Superior, mainly south of Wawa. The cause of the dieback is not known but could involve acidic fog, climate change and/or natural factors. The zone is considered to be too remote and too extensive to implicate a local point source of phytotoxic emissions. Several species of white birch trees and their hybrids appear to be involved.

Project Description:

The project involves several facets. These include identification of tree species using electrophoresis of bud tissues, collection of increment cores for preliminary growth studies, collection of fog samples, sample collection of soil, foliage, sap and roots for chemical composition studies, and establishment of permanent plots for plant community studies. Most of the former have been completed. More definition of the affected area needs to be carried out.

Product:

Preliminary analysis of results from 300 trees indicate that the older tree population is dominated by Betula cordifolia while the younger population is dominated by B. papyrifera. Because the former are favoured by cooler climatic conditions, it is speculated that recent (less-favourable) climatic changes are having a role in the dieback. Recent climatic changes

are also evident in the past few years showing a dramatic reduction in the incidence of fog, hence, few samples of fog water could be collected.

Soil samples collected from the pits dug at each site indicate that the surface soils are extremely acidic (pH 2.9) and aluminum forms about 50% of the CEC which is very small. There is very little buffering capability and K and Mg concentrations in the soil also very low. Bean plants growing in soils collected in this area developed toxicity symptoms.

Sap chemistry indicates higher concentrations of aluminum and other constituents in younger trees. Analysis of other data is underway.

Application of Results:

The problem offers an excellent opportunity to investigate the cause of an advanced forest dieback problem and the results could be extrapolated to areas with less severe dieback symptoms.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Interaction of simulated acidic rain and insect defoliation on sugar maple

Project Leader:

W.D. McIlveen

Purpose:

To determine if insect defoliation of sugar maple is mediated by acidic precipitation

Background:

Extensive defoliation of sugar maple trees by Forest Tent Caterpillar has occurred historically in the Muskoka area where current forest dieback problems are occurring. The relative roles and possible interaction of acidic deposition and insect defoliation are uncertain and therefore need clarification.

Project Description:

In the present study, the possible interaction of these two agents is being investigated in controlled conditions with exposures to simulated acidic rain. The work was carried out mainly at the Controlled Environment Facility at Brampton.

Established potted sugar maple seedlings from the Muskoka area were subjected to artificial defoliation and feeding by Forest Tent Caterpillar larvae. Growth and overwintering of trees was monitored. Caterpillar larvae were also subjected to preference tests of maple foliage treated with simulated acidic rain and their growth and performance monitored.

Product:

Indications are that the defoliated trees grew more slowly than non-defoliated trees. Severely defoliated trees were less likely to survive over winter. Acidic precipitation did not show any direct effects on the trees during the duration of this study.

Caterpillars grew faster and larger when feeding on acid-treated trees. The implications of this observation are unclear at this time but larger caterpillars could produce more offspring and thus subsequent generations could have a greater impact on the maple forest.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

International early warning diagnosis for forest decline

Project Leader:

W.D. McIlveen

Purpose:

To develop methodologies for measuring biochemical of physiological injury to trees prior to the onset of visible dieback symptoms

Background:

Forest decline is a major concern in parts of Europe including West Germany. Symptoms observed on affected trees are not reversible in many instances and this decreases the potential for managers to react to the development of decline. The methodologies employed in Europe might have application in Ontario in determining similarities between the situation in Europe and the situation in Ontario.

Project Description:

A program of foliage collection and analysis with project components similar to those used in Germany was carried out in Ontario in 1987 and 1988. Samples of foliage from sugar maple, white pine and Norway spruce were collected at 16 sites (12 only for spruce) across the pollution gradient from southwest to southeast. Six or 8 trees were sampled per site and conifer foliage was separated into 3 age classes.

Contact angle measurements for water droplets on foliage and Hartel tests of fresh foliage samples were made. Pigment analysis included chlorophylls a & b, carotene, lutein, and several xanthophylls. The ratios of the latter have been indicators of tree health status in Europe.

Product:

Results show that there was a strong trend towards characteristics of earlier aging of foliage such as leaf wetting and internal chemistry while chlorophyll content was higher at sites in the most polluted in Ontario. It is difficult to separate ozone and acidic deposition potential effects since these are co-deposited. Magnesium distribution patterns in conifer foliage may be more useful in defining nutritional stresses.

Application of Results:

Although trends were detected, the application of the present early diagnosis tests is probably limited due to inherent variability in Ontario plant material. Application of the tests to an individual tree or plant is unlikely to provide a definitive explanation of its condition.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Effects of soil fertility applications on sugar maple decline

Project Leader:

W.D. McIlveen

Purpose:

To determine the potential for inorganic fertilizers to reverse symptoms of dieback of sugar maple

Background:

Requests from concerned citizens and other groups have been received concerning potential methods to save trees that are suffering dieback symptoms. One purported means of accomplishing this is the application of commercial fertilizer products. There is currently very little information on which to base recommendations for fertilizer applications in response to these requests, especially as they apply to the Ontario situation. The present study was developed in response to this need.

Project Description;

In 1988, the Ontario Ministry of the Environment funded a one year pilot fertilization program. The study involved 4 sites in the Muskoka-Peterborough area with two sites each on and off the Precambrian Shield. At each site, individual trees were identified and classed as healthy or exhibiting dieback symptoms. In each of these classes, fertilizers or lime were applied to three replicated trees. Prior to treatment, foliage and soil were collected from each tree. Tree condition was assessed annually and samples of soil and foliage were collected.

Additional genetic information from each tree was determined under a different Ontario Ministry of the Environment funded project.

Product:

Analysis of the data with respect to changes in tree condition or foliage and soil chemistry caused by fertilizer application are currently in progress.

Application of Results:

The two prime benefits of this project include the diagnosis of nutrient deficiency (if this is indeed the problem resulting in the tree dieback) and will contribute to the development of recommendations for fertilizer applications for property owners.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Tree seedling plot study

Project Leader:

W.D. McIlveen

Purpose:

To evaluate the effects of lime application either on tree growth or in foliar chemistry at tree seedling plots established in northeastern Ontario.

Background:

The application of agricultural limestone is a routine procedure to overcome acidic materials in soil. It would appear natural consider this approach in dealing with the potential effects of acidic precipitation on soils. The application of limestone was included as one of the treatments of tree seedling plots established in northeastern Ontario.

In addition to neutralizing the acidic components in the soil, several metals (including micronutrients) would become less available while the supply of calcium would be expected to increase. Such changes would likely become apparent in the foliage chemistry and possibly in the growth of the tree.

Project Description:

In 1979-81, tree seedling plots were established throughout the southern portion of Northeastern Ontario. These plots consisted of one to five species with 100 trees of each. Various treatments were applied for 3-4 years to test the response of the trees to the treatments, one of which was agricultural limestone. Condition, survival and growth of the trees was monitored for several years and the trees were tended during that period.

The present study was designed to take advantage of the work which had already been completed. In 1990, eight plots with Jack pine and red pine were selected for evaluation. The sampled plots were located at Novar, St. Joseph's Is., Huff Lake, Parkinson, Campbell Twp, Street Twp, Gogama, Burwash and Algonquin Park. Tree heights were not determined because the trees were too crowded to make measurements. Stem diameters were measured and tree crown conditions were evaluated. Foliage and soil (0-5, 0-15 cm) samples were collected for analysis (four replicates for each treatment).

Product:

A report incorporating the results of this project will be prepared when the analytical portion of the study is completed.

Application of Results:

The effectiveness and consequences of applying limestone to tree seedings as part of forestry practices to overcome acidic inputs will be documented.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

An inter-agency study of acidic rain and hardwood decline in North America

Project Leader:

W.D. McIlveen

Purpose:

To develop a standardized method for assessing hardwood forest dieback.

Background:

Various governmental agencies in North America are concerned about the health of forests in their respective jurisdictions where tree dieback has been identified. The methods used by each are not necessarily standardized; hence, data are not directly comparable. To ensure that a unified approach is used, an intergovernmental cooperative study was initiated between a number of Canadian and U.S. groups. These included Ontario, Quebec and New Brunswick plus most border states from Wisconsin to Maine.

Product:

A standardized method for establishing tree plots and evaluating trees was developed and validated. In Ontario, 24 permanent plots were installed and monitored by the Canadian Forest Service, Forest Insect and Disease Survey (FIDS) in 1988. Plot selection was aided through advice from Phytotoxicology staff. All plots were evaluated again in 1989 and 1990.

Each plot consists of 5 subplots of a fixed area. Each tree in the plot was scored for condition according to the project quality assurance manual. A number of plots are located in close proximity to those set up by the Ontario Ministry of the Environment and therefore they provide a means of comparison between the two projects.

The results for 1988 indicate that the program was very successful regarding completion of plot establishment and quality of data. Data for the study period suggest that overall tree condition improved slightly but not at sites in the heaviest deposition zone (may have actually decreased).

Application of Results:

The study will help to determine rate of change of forest (sugar maple) dieback and the role of management practices and acidic deposition in that change. In addition, the effort developed a spirit of cooperation among the agencies involved and a set of reference study sites that can be used when comparing data among diverse study areas.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Historical foliar sulphur project

Project Leader:

W.D. McIlveen

Purpose:

To determine if changes in foliage composition has changed on a regional basis.

Background:

Changes in contamination of the terrestrial environment are frequently difficult to determine because the original conditions have not been documented. One of the oldest data sets encountered for Ontario consists of sulphur analysis for foliage of several tree species conducted in 1944. The study was centred on emissions from Sudbury but extended to sites remote from Sudbury. The locations and analytical procedures were documented. It was believed that this data set could be compared with current situation by collection of new samples at the sites described and making allowances for the analytical techniques.

Project Description:

The historical data were obtained from the Provincial Archives. The data were reviewed regarding sample sites, dates and other relevant information. As many as possible of the historical sites were visited and a comparable set of samples were collected for white pine, red pine, trembling aspen and white birch. The samples have been submitted for chemical analysis for sulphur as well as a suite of metals. Methods for sulphur analysis at each time period will be compared and a correction factor applied when the results become available.

Application of Results:

Comparison of data between the two study periods would contribute to our knowledge of the effects of sulphur deposition to vegetation resulting from long range transport. More specifically, it may be possible to determine whether conditions have improved or deteriorated (i.e., has the sulphur content of vegetation increased or decreased). The data could also contribute to our knowledge of the distribution of metals (notably cadmium) in the food of wildlife.

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH
PROJECT SUMMARY: 1990-1991

Project Title:

Wildlife forage project

Project Leader:

W.D. McIlveen

Purpose:

To determine concentrations of cadmium and other metals in forage utilized by deer and moose.

Background:

Previous studies by MNR have shown major game animals to have elevated concentrations of cadmium in their tissues. The degree of contamination appeared to be related to sensitivity of the soil in the sample areas to acidic deposition. An understanding of the effects of acidic deposition on availability of cadmium through the forage of the animals is necessary. The initial approach was to determine cadmium levels in forage plants.

Project Description:

The field work was completed cooperatively with MNR staff. The first part of this included analysis of aquatic vegetation normally consumed by moose. The second part involved analysis of terrestrial vegetation consumed by moose and deer. Foliage, twigs, soil and moss were collected in late 1989 and these analyses have just been completed.

Product:

Aquatic forage plants preferred by moose (*Utricularia*) accumulated more cadmium in poorly buffered watersheds. This probably had a role in the elevated cadmium burden found in moose tissues from these areas. An indication of the terrestrial sources of cadmium will come from the present study of vegetation. Two of the most frequently utilized browse species (birch and aspen) are known accumulators of cadmium (and notably zinc).

Information from MOE, MNR, and other agencies will be compiled and compared.

Application of Results:

Because it would not be possible to cause wildlife to alter their choice of food plants, any actions to reduce cadmium uptake into vegetation must include measures to reduce acidification of soil. This project then provides additional justification for acid gas abatement.

ACID PRECIPITATION OFFICE

ACID PRECIPITATION OFFICE
PROJECT SUMMARY: 1990-91

Project Title:

NO_x/VOCs Management Plan

Project Leader:

W. H. Chan

Purpose:

To develop a plan that will address domestic ground level ozone air quality through multi-stakeholder consultation.

Background:

In the fall of 1988, the Canadian Council of Minister's of the Environment (CCME), agreed to develop a plan to address ground level ozone levels in Canada. After stakeholder consultations, a final plan was released in October 1990 which was approved in-principle in November, 1990 by CCME with federal-provincial agreements to be signed by November, 1991. The plan is multi-phased with the first phase addressing peak ozone levels and exceedances by NO_x and VOC controls in four broad source categories: transportation, power generation, product modification and industrial facilities. The plan is composed of a national prevention component and a regional remediation component. Being one for the identified ozone non-attainment area (Windsor-Quebec Corridor), Ontario will identify and implement regionally specific measures. Consultations between Air Resources Branch and the Acid Precipitation Office and appropriate stakeholders have been underway to identify feasible actions to be implemented by 1995 and 2000 to meet corresponding emissions reduction targets.

Second and third phases of the plan will be developed in 1994 and 1997 to define further reductions to consistently attain the 82 ppb ozone objective by 2005 in all areas of Canada.

Product:

The final Phase 1 NO_x/VOCs Management Plan was released in May, 1991. A Cabinet submission of Ontario's proposed plan to meet the requirements is scheduled early in 1992 followed by the signing of a federal-provincial agreement.

ACID PRECIPITATION OFFICE
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Product:

The final Phase 1 NO_x/VOCs Management Plan was released in May, 1991. A Cabinet submission of Ontario's proposed plan to meet the requirements is scheduled early in 1992 followed by the signing of a federal-provincial agreement.

Implications:

Implementation of this plan will not only improve ground level ozone air quality, but also reduce potential global warming and acid deposition due to ozone and nitrates, respectively.

Publications:

1. Management Plan for Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs), Phase 1, November 1990.

2. Management Plan for Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs), Phase 1 Summary Report, November 1990.

ACID PRECIPITATION OFFICE
PROJECT SUMMARY: 1990-91

Project Title:

Post-94 Control Strategies

Project Leader:

A. Deshpande

Purpose:

To ensure that Ontario's Federal/Provincial commitments for sulphur dioxide and nitrogen oxides are met consistently after 1994.

Background:

Ontario's Countdown Program limits total sulphur dioxide emissions from all sources to 877 kt from 1994 onwards. Because of uncertainties about growth in economic activity these emissions could exceed this figure after 1994. Moreover, the target deposition rate of wet sulphate of 20 kg/ha/yr may be insufficient to protect all areas sensitive to acid rain impact in Ontario.

Nitrogen oxide emissions are considered in this paper because NO_x is one of the precursors of acid rain and also plays an important role in oxidant formation in Ontario's Windsor-Quebec Corridor (WQC). Therefore, it may be necessary to reduce SO_2 and/or NO_x emissions from existing sources by up to 100,000 - 200,000 tonnes per year in order to achieve these objectives.

Product:

A paper was prepared jointly by the Fiscal Planning and Economic Analysis Branch and Acid Precipitation Office (APIOS) covering control technologies and related costs to obtain further reduction of 10, 30, and 50 percent in SO_2 and NO_x emissions from stationary sources in Ontario from the base year 1994.

This paper is based on earlier studies done by:

(a) Senes Consultants Ltd. on "Countdown Acid Rain: Future Abatement Strategies" (1989) and

(b) VHB Research and Consulting Inc. on "Nitrogen Oxides and Volatile Organic Compounds Abatement Cost Study" (1989)

under Ministry programs.

Other economic incentive instruments to achieve the Ministry goals have been briefly reviewed and some examples given.

Publications/Reports/Presentations:

Approval is presently sought from the Ministry to release this paper.

Implications:

A 50% reduction of SO_2 or NO_x emissions beyond those required by the Countdown Program from stationary sources is technically feasible but will cost several hundred million dollars. While all stationary emitters would probably protest further reductions, greater resistance to Post-Countdown reductions is expected under an Equal Percent Reduction Strategy than Least-Cost Strategy.

The results of this study do not indicate whether priority should be given to SO_2 or NO_x abatement nor were the economic implications of Post Countdown abatement costs on individual plants or firms assessed.

Economic incentives like tradable emission permits or emission charges could enhance the Ministry's enforcement capabilities for a Post Countdown Abatement Strategy.

ACID PRECIPITATION OFFICE
PROJECT SUMMARY: 1990-91

Project Title:

Countdown Compliance

Project Leader:

A. Deshpande

Purpose:

To ensure that the four corporate sources of SO_2 in Ontario comply with the Countdown Acid Rain regulations.

Background:

In 1985 regulations were passed which placed acid gas emission limits on the four corporate sources of SO_2 in Ontario which collectively, emit over 80% of the province's sulphur dioxide emissions.

The legal limits (in kilotonnes) for the four companies are:

	1986	1994
Inco	685	265
Falconbridge	154	100
Algoma (Wawa)	180	125
Ontario Hydro	370	175

Each of the companies is required to submit regular emission reports and to date, each company has reported emissions which are less than their regulation limit. Progress reports, showing methods used and costs, are required from each company every six months. The government reviews these progress reports and a summary and analysis report is prepared and published.

Product:

During 1990-91, the ninth and tenth progress reports have been submitted by the four companies. The government's responses to the ninth report and the tenth report are available.

Implications:

Although the companies have met the current emissions reduction limits, further reductions beyond 1994 must be considered to protect aquatic ecosystems. Some companies have indicated that further reductions may be possible.

ACID PRECIPITATION OFFICE
PROJECT SUMMARY: 1990-91

Project Title:

Communications Program

Project Leader:

D. Corrigan/G. Merchant

Purpose:

To increase public awareness in Ontario and internationally of the science of acid rain, its effects in Ontario and the Countdown SO_2 abatement program.

Background:

The Communications program was initially aimed at obtaining support in the U.S. for acid gas controls and to publicize Ontario's acid gas control program. Public relations materials that were prepared since 1985 reflected this theme. With the passage of the Clean Air Act Amendments in November, 1990, the focus of the program shifted from increasing awareness of the issue within the U.S. to publicizing recent scientific findings within Ontario as a result of the abatement actions of both countries.

Product:

The "Countdown Acid Gas Control Program 1985-94" brochure was updated to include more recent effects, aquatic recovery information as well as abatement actions by both Canada and the U.S. A stand alone bilingual display to accompany the brochure was designed for use by Ministry staff or upon request from other agencies. A draft of a Health Effects Fact Sheet was prepared by Acid Precipitation Office staff and an annual report of program findings from 1989-90 was prepared and distributed to a mailing list of 500 individuals and agencies.

Acid Precipitation Office staff participated in a number of public relations presentations at schools, colleges and universities. In addition, the Office handles on average 10 telephone information requests per day and 5 walk-in requests for technical information on acid rain. The number of requests for information on NO_x/VOCs management and global warming has increased during 1990-91.

A communications strategy for 1991-92 was prepared.

ACID PRECIPITATION OFFICE
PROJECT SUMMARY: 1990-91

Project Title:

Global Warming Strategy Development

Project Leader:

G. Endicott/I. Leung

Purpose:

To establish a greenhouse gas emission reduction target for Ontario and to develop a strategy to meet that target.

Background:

The Ministry of Energy issued a discussion paper in March 1990 which stated that its policies would result in greenhouse gas emissions lower than 1989 by 2000. The City of Toronto has adopted a 20% reduction in CO_2 from 1988 levels by 2005 while the federal government proposed stabilization of CO_2 and other greenhouse gas emissions at 1990 levels by 2000.

In January 1991, the Ministries of Environment and Energy jointly commissioned a report from a coalition of environmental groups on possible measures to reach the 20% reduction goal through energy related CO_2 reductions. The report, entitled "Degrees of Change, Steps Towards an Ontario Global Warming Strategy" was completed in June 1991. It contained recommendation on how to reach a 26% reduction of about 75% of Ontario's energy related CO_2 emissions from 1988 levels by 2005.

Product:

Requests for proposals due in the process of being evaluated or sent out on the following:

(a) Inventory of Ontario Greenhouse Gas Emissions (jointly with Energy)
(b) Scoping of a Global Warming Science Program
(c) Implications of Measures to Reduce Greenhouse Gas Emissions in Ontario: 1988-2005.

A Cabinet submission on a global warming program failed in May 1991. Cabinet requested a new submission on further progress for December 1991 and a second submission on a program by summer 1992.

Implications:

The establishment of a greenhouse gas emission reduction target and the associated strategy to meet that target will require the cooperation of all levels of government and interested groups. The government will not be able to proceed with implementation of the strategy without enhanced public awareness of the issue and widespread social cooperation.